A COMPARATIVE EVALUATION OF FRACTURE RESISTANCE AND PUSH-OUT BOND STRENGTH TO ROOT DENTIN USING THREE DIFFERENT ROOT CANAL SEALERS-AN INVITRO STUDY.

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DECLARATION BY THE CANDIDATE

I hereby declare that this dissertation titled **"A COMPARATIVE EVALUATION OF FRACTURE RESISTANCE AND PUSH-OUT BOND STRENGTH TO ROOT DENTIN USING THREE DIFFERENT ROOT CANAL SEALERS-AN INVITRO STUDY"** is a bonafide and genuine research work carried out by me under the guidance of **DR.K.AMUDHALAKSHMI**, **Associate Professor,** Department Of Conservative Dentistry and Endodontics, Tamil Nadu Government Dental College and Hospital. Chennai -600003.

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DECLARATION

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ABSTRACT.

Aim: The purpose of this in-vitro study is to compare fracture resistance and push-out bond strength to root canal dentin using three different root canal sealers.

Materials and Methods: Fifty-five extracted single-rooted mandibular premolars of similar sizes were selected randomly and decoronated to a length of 14mm. Forty teeth were subjected for evaluation of fracture resistance and remaining fifteen for push-out bond strength.I) For fracture resistance, teeth were randomly divided into 5 groups (n=10) for each experimental groups and (n=5) for each control groups. In group 1, the teeth were left unprepared and unfilled (negative control), and in group 2, the teeth were left unobturated (positive control). The rest of the roots were prepared by using the ProTaper System up to a master apical file size of F3: group 3, bioceramic sealer (Endosequence BC sealer) + gutta-percha; group 4, mineral trioxide aggregate based sealer (MTA Fillapex) + gutta- percha; and group 5, epoxy resin–based sealer (AH Plus Jet) + gutta-percha. All root specimens were stored for 2 weeks at 100% humidity to allow the complete setting of the sealers. Each specimen was then subjected to fracture testing by using a universal testing machine at a crosshead speed of 1.0 mm/min^{-1} until the root fractured. The force required to fracture each specimen was recorded. II) For push-out bond strength, fifteen decoronated teeth were randomly divided into 3 groups. All roots were prepared in similar way as described earlier: group 1, bioceramic sealer (Endosequence BC sealer) + gutta-percha; group 2, mineral trioxide aggregate based sealer (MTA Fillapex) + gutta- percha; and group 3, epoxy resin–based sealer (AH Plus Jet) + gutta-percha. Two horizontal sections were prepared at a thickness of 1mm ± 0.1 in the coronal parts of each root, resulting in (n=10) specimen in each group. The test specimens were subjected to the push-out test method using a universal testing machine with loading speed of 1.0 mm/min^{-1} and push-out data were recorded. Data's obtained were analyzed statistically by one-way analysis of variance (ANOVA) and the post hoc tukey test, with significance set at $P < 0.05$.

Results: There was no significant difference between groups 3, 4 and 5 ($P > .05$) in fracture resistance values. Whereas, groups 1 and 3 had significantly higher bond strength values than the group 2 ($P < .05$). However, there was no significant difference between groups 1 and 3 ($P > .05$) in bond strength values.

Conclusion: All the three root canal sealers examined in this study strengthened the prepared root canals with increased fracture resistance. MTA Fillapex had the lowest push-out bond values to root dentine compared with other two sealers used in this study.

Key words: *Endosequence BC sealer, AH Plus Jet, MTA Fillapex, fracture resistance, push-out bond strength.*

LIST OF TABLES.

S. NO	TABLES	PAGE NO.
1	**Fracture resistance values in Newton's (N).**	35
2	**One-way Analysis Of Variance (ANOVA) test for Fracture resistance.** **(A)** Mean and Standard deviation. **(B)** Statistical test.	36
3	**Post Hoc Tukey test for multiple comparison among the groups for Fracture resistance.**	37
4	**Push-out bond strength values in Newton's (N).**	38
5	**Push-out bond strength values in Megapascal's (MPa).**	38
6	**One-way Analysis Of Variance (ANOVA) test for Push-out test.** **(A)** Mean and Standard deviation. **(B)** Statistical test.	39
7	**Post Hoc Tukey test for multiple comparison among the groups for Push-out bond strength.**	40
8	**Mode of bond failures.**	41

LIST OF GRAPHS.

S.NO	GRAPHS	PAGE NO.
1.	**Mean Values Of Fracture Resistance For All Groups.**	42
2.	**Mean Values Of Push-out Bond strength For All Groups.**	42

ABBREVIATIONS.

MTA	Mineral trioxide aggregate.
BC	Bioceramic.
EDTA	Ethylene Diamine Tetra Acetic Acid
NiTi	Nickel Titanium.
NaOCL	Sodium Hypochlorite.
MPa	Megapascal’s
N	Newton’s.

CONTENTS.

S.NO	CONTENTS	PAGE NO.
1	INTRODUCTION	1-4
2	AIM AND OBJECTIVES	5
3	REVIEW OF LITERATURE	6-22
4	MATERIALS AND METHOD	23-34
5	RESULTS	35-45
6	DISCUSSION	46-59
7	SUMMARY	60-62
8	CONCLUSION	63
9	BIBIOGRAPHY	i-x

Introduction

INTRODUCTION.

Endodontics is a speciality which is very receptive to new ideas and concepts. According to, recent epidemiological data endodontics are situated on the “right” pathway, as more than 90% percentages of teeth can be retained through contemporary endodontic therapy.[18]

But not all root canal treatments are successful. Vertical root fracture is the most frustrating complication to the therapy.[80] Being a serious clinical concern, with an unfavorable prognosis,[80,46] it leads to the extraction of the tooth or resection of the affected roots.[43,96]

Endodontically treated teeth are widely considered to be more susceptible to fracture than vital teeth. The reason most often reported have been the removal of tooth structure during endodontic treatment i.e. excessive widening of root canals,[48,66] the dehydration of dentin after endodontic therapy, excessive pressure during obturation, and loss of collagen cross-linking.[99]

The modulus of elasticity and, importantly, the fracture toughness of teeth might be reduced not only by incomplete root development and losses of hard tooth substance but also by changes in the moisture content of dentin with aging and with the loss of vital pulp tissue.[42] Increased amounts of physiologic and pathologic translucent dentin also occur with aging, which is associated with loss of moisture and leads to an increased risk for brittle fracture.[41,42]

Risk factors for tooth fracture during and after endodontic therapy includes tooth type, canal wall thickness and root canal diameter and cross-sectional shape, root canal preparation instruments, preparation methods and the size of the master apical file.

Excessive removal of dentin due to over instrumentation and the presence of noncircular canals and thin canal walls, particularly with certain tooth types, increase the risk for root fracture.[70] Until relatively recently, the choice of materials for root canal sealers and root canal filling was very limited. Stable adhesion and an elastic modulus similar to root canal dentin are two key factors for root filling material to improve fracture resistance of endodontically treated teeth.[30]

Hence any material that can compensate for this weakening effect could be useful. To reinforce the instrumented teeth against fracture; sealers are used in conjunction with a core filling material.[95]

The first gutta-percha root canal filling material was introduced in dentistry in 1848, over the years many techniques have been developed to facilitate a three dimensional filling using this material. Typically, gutta-percha is used either as a solid cone or plasticised by heat, together with root canal sealer, to obliterate the internal confines of root canal system.[18] However disadvantage with gutta-percha and sealer is its inability in creating a dependable seal for root canal system.[35]

Root canal sealers can be grouped according to their component such as zinc oxide eugenol, calcium silicate based, epoxy resin based or methacrylate resin based. Conflicting reports have been published regarding effect of endodontic sealers on the fracture resistance of roots. Some studies have indicated that neither epoxy resin based sealers nor zinc oxide eugenol based sealers were able to strengthen endodontically treated roots significantly,[4,48] although other studies had reported positive results for epoxy resin based sealers.[17,88]

Because of poor adhesion of gutta-percha to dentinal surface, sealer should present adequate flow for filling gaps between canal walls and gutta-percha cones; thus contributing to better quality of sealing.[4,57] Bond strength of sealer to root canal dentin contribute a major role in quality of sealing. During post-space preparation, root canal filling material might get dislodged, creating voids in the obturation which in turn affect the quality of seal.[16,19,20,65]

To measure the interfacial shear strength developed between different surfaces, push-out test is used thus providing additional information on evaluation of adhesion properties of sealer to canal dentin. So in this study, push-out test intends to assess to which extent the core material and sealer are bonded together into a solid mass as well as bond strength to canal wall.[15,85]

Recently, a new bioceramic root canal sealer has been introduced, which is known commercially as Endosequence BC sealer (Brasseler USA, Savannah, GA). Endosequence BC Sealer is a premixed and injectable endodontic sealer, and its nanoparticle size allows it to flow readily into canal irregularities and dentinal tubules. It is hydrophilic and uses moisture in dentinal tubules to initiate and complete its setting reaction. In addition, no shrinkage occurs on setting, resulting in a gap-free interface between the gutta-percha, sealer, and dentin.[31]

AH Plus Jet sealer (Dentsply De Trey, Konstanz, Germany) is a resin-based root canal sealer and has the same formulation as AH Plus sealer. According to the manufacturer, it has an innovative delivery system that eliminates the need for manual mixing before use, while enabling direct and precise placement into the canal or onto a traditional mixing pad. AH Plus Jet sealer features an innovative double-barrel syringe that automatically and precisely mixes the paste-to-paste formula in the necessary 1:1 ratio.

Another recently introduced root canal sealer is MTA-based root canal sealer, MTA Fillapex (Angelus Solucxoes Odontologicas, Londrina, Brazil). According to the manufacturer, it contains salicylate resin, nanoparticulated resin, bismuth trioxide, diluting resins, natural resin, and MTA. They also claim, of low solubility and expansion during setting.[11]

In the present study an attempt has been made to measure and compare the fracture resistance of root canals obturated with three different endodontic sealers namely MTA based, epoxy resin based, calcium silicate based root canal sealer along with gutta-percha and compare push-out bond strength of these sealers to root canal dentin.

Aim and Objectives

AIM:

The purpose of this in-vitro study is to compare fracture resistance and push-out bond strength to root canal dentin using different root canal sealers.

OBJECTIVES:

1. To evaluate and compare the fracture resistance of the teeth obturated with following sealers.
2. To evaluate and compare the push out bond strength of following sealers to root canal dentin.
    A. Bioceramic based root canal sealer (Endosequence BC).
    B. MTA based root canal sealer (MTA Fillapex).
    C. Epoxy resin based root canal sealer (AH-Plus Jet).

Review of literature

I - FRACTURE RESISTANCE.

Historically many materials have been used to fill the root canals.

The most commonly used core filling material is gutta-percha, but this material does not seal the canal when used alone. Therefore a root canal sealer or cement is required to adhere to the dentin and to fill the irregularities and minor discrepancies between the core filling material and canal walls, thus providing a fluid tight seal.

In **1800's and before** materials ranging from tin foil, lead foil, gold foil, cotton pellets with various medicaments of wood, spunk, plaster of paris, oxychloride of zinc, zinc oxide, paraffin, copper points and various other concoctions were used to fill root canals.

Asa Hill (1847) developed Hill's stopping which consisted of bleached gutta-percha and carbonate of lime and quartz; thus making the advent of gutta-percha as a root canal filling material in endodontics.

Bowman (1867) claimed (before the St. Louis Dental Society) the first use of gutta-percha for filling in an extracted first molar.

S.S. White Company (1887) began to market gutta-percha points to the profession.

Rollins (1893) introduced a new type of gutta-percha to which he added vermilion.[18]

Tidmarsh B (1978)[86] described and evaluated the use of resin sealed root canals i.e. low viscosity resin and effect of acid rinse 50% citric acid as root canal irrigant under scanning electron microscope**.** They had reported the nature of this resin to the acid rinsed canal walls, adaptation of resin and suggested a possible clinical use.

Lewinstein I and Grajowar R (1981)[49] evaluated the hardness of dentin taken from teeth that were extracted at different periods after root canal treatment was determined. The results show that dentin hardness is not altered after endodontic treatment.

Sornkul E and Stannard JG (1992)[77] evaluated the resistance to fracture of mandibular premolar roots before and after endodontic and restorative procedures after applying vertical and lateral (45-degree) forces. They had recorded the highest resistance to fracture for untreated roots. Factors of importance to prevent fracture were found to be (a) the amount of remaining tooth structure; (b) strength of post and core; and (c) bonding between core material and dentin. These factors suggest that a composite core following the use of EDTA to remove the smear layer may be a successful treatment when sufficient tooth structure remains.

Onnink PA et al (1994)[55] compared the incidence of incomplete root fractures among mandibular incisors treated with different techniques i.e. (a) no canal preparation, (b) canal preparation, (c) canal preparation and obturation with laterally condensed gutta-percha, (d) canal preparation and obturation with thermoplasticized gutta percha on a central carrier (Thermafil) and (e) canal preparation and obturation with thermoplasticized injectable gutta percha (Ultrafil). They had concluded the lowest incidence of stained incomplete fracture was found in the no canal preparation group. The canal preparation, lateral condensation, Ultrafil, and Thermafil groups had more incomplete fractures than the no canal preparation group.

Saw LH and Messer HH (1995)[66] evaluated root strain of different obturation techniques i.e. lateral condensation with gutta percha, Obtura thermoplastic and thermoplasticized gutta percha on a central carrier (Thermafil) solid core obturation techniques. They had concluded that the technique of obturation significantly influenced the root strains, with the Obtura generating the highest strains, Thermafil group showed significantly less strain than the Obtura or lateral condensation groups. A large proportion of strain in the Obtura and Thermafil groups was found to be thermal strain and the mean load required to cause vertical root fracture was five to six times higher than the load used in obturation.

Cobankara FK et al (2002)[17] studied the effect of Ketac-Endo and AH 26 root canal sealer on resistance to root fracture and also evaluated the effect of smear layer. They had found that roots that were obturated with AH 26 sealers and lateral condensation technique were significantly stronger than the roots whose canals were instrumented but not obturated and presence or absence of the smear layer did not cause any significant effect on root fracture resistance of the teeth.

Lertchirakarn V et al (2002)[48] studied effect of root canal sealers on vertical root fracture resistance of endodontically treated teeth using gutta percha, Tubliseal , AH Plus and Ketac-Endo root canal sealer. He stated that Ketac- Endo filled teeth fracture forces are higher as compared forces for Tubliseal and AH Plus and most fracture lines are in buccolingual direction.

Lawley G R et al (2004)[44] evaluated intracoronal delivery of an apical barrier of mineral trioxide aggregate (MTA) placed ultrasonically, non-ultrasonically or ultrasonically with the addition of an intracanal composite resin provided a better seal against bacterial leakage and was to determine whether intracoronal composite resin or gutta percha and sealer placed against an apical barrier of MTA provided greater resistance to root fracture. They had concluded that treating immature apex with an

MTA apexification procedure followed with an internal bonded composite appears to offer a favourable prognosis and after 90 days, the ultrasonically placed MTA followed with composite provided a significantly better MTA seal than without ultrasonic. In addition, the ability of a flowable composite resin to be bonded intracoronal against a 4mm apical barrier of MTA significantly increased the fracture resistance, compared with an MTA barrier with gutta percha and sealer.

Teixiera F B et al (2004)[82] evaluated the fracture resistance of endodontically treated teeth filled with either gutta-percha or a resin based obturation material. He showed that filling the canals with the new resin based obturation material increased the in vitro resistance to fracture of endodontically treated single-canal extracted teeth when compared with standard gutta-percha technique.

Lam et al (2005)[43] studied fracture loads in tooth roots after canal were prepared by hand and rotary instrumentation in which he prepared canals with stainless steel hand file (K-files) and two nickel titanium rotary techniques i.e. Lightspeed (LS) and Gratertaper (GT) files with size of 25 as master apical file and then obturated with AH 26 root canal sealer. They concluded that both rotary instrumentation technique showed higher fracture loads than the hand K-files and proved that greater apical enlargement (with light speed) or increased canal taper (with Grater Taper files) did not increase fracture susceptibility of tooth roots.

William C et al (2006)[98] compared the cohesive strength and stiffness of Resilon and gutta percha under dry condition and after 1 months of water storage to determine whether they are enough to reinforce roots. They had concluded that there was no significant differences were seen between the mechanical properties of two polymers;

depicting that both materials had cohesive strength and modulus of elasticity values that are low to reinforce the roots of endodontically treated teeth.

Schafer E et al (2007)[67] investigated root reinforcing capability of the resin based adhesive root canal filling against the fracture of endodontically treated roots. They had filled root canals with gutta-percha/AH Plus and RealSeal and concluded that root canal obturated with RealSeal Significantly increases the fracture resistance of instrumented roots.

Soares CJ et al (2007)[75] evaluated the effect of endodontic treatment and storage time on the flexural and ultimate tensile strength of root dentin after preparing canal in bovine teeth with hand K file upto master apical size of 50; these were obturated with gutta percha-zinc oxide eugenol root canal sealer (Endofill) and then subjected for micro tensile testing immediately and after 7 days, 15 days 30days. They had concluded that that endodontic treatment potentiated by time negatively alters flexural and ultimate tensile strength of the root dentin.

Ulusoy et al (2007)[90] compared fracture resistance of root obturated with three different materials like gutta-percha/AH-26, Resilon-Epiphany and gutta-percha/Ketac-Endo Aplicap. He concluded that gutta percha/AH 26 obturated root canal has increased fracture resistance of instrumented root canals compared with Resilon-Epiphany and Ketac-Endo Aplicap-gutta percha.

Wilkinson KL et al (2007)[97] evaluated the fracture resistance gained by filling root canals of simulated immature teeth with either Resilon, gutta percha, a self-curing flowable composite resin (BisFil 2B), or a self-curing hybrid composite resin (BisFil II). They had stated that the fracture resistance of the BisFil II hybrid composite resin group was significantly superior to the unrestored positive controls and the gutta percha along with root canal sealer group.

Ribeiro F et al (2008)[59] evaluated the influence of different endodontic materials such as gutta percha/Endofill, gutta percha/Sealer 26, gutta percha/AH Plus, gutta percha/Epiphany and Epiphany/Resilon on root fracture susceptibility. They had concluded that tested materials in study were not able to increase the fracture resistance of root canals submitted to chemo mechanical preparation.

Shetty R et al (2009)[71] evaluated and compared the fracture resistance of endodontically treated roots filled with Resilon and gutta percha/AH Plus. They had concluded that root filled with Resilon increased the in vitro fracture resistance of endodontically treated roots compared to standard gutta percha techniques and stated that Adhesive sealers are more beneficial in increasing the fracture resistance of endodontically treated teeth.

Kazandag MK et al (2009)[38] compared fracture resistance of root using different canal filling systems such as AH Plus/gutta-percha, Resilon/Epiphany, Active GP cone/Active GP sealer and Active GP sealer/gutta-percha. They concluded that system which aims to form monoblock system were not superior to the conventional AH Plus/gutta-percha technique in terms of fracture resistance. The fracture resistance of root using Active GP with laterally compacted gutta-percha showed significant reduced compared to AH Plus/gutta-percha group.

Wadhwani KK and Gurung S (2009)[95] studied the fracture resistance of root filled with Endomethasone, AH-plus and Resilon-Epiphany sealer. They had concluded that there was significant difference between these three root canal sealers to that control group. But no significant differences were found among the three experimental groups.

Chadha R et al (2010)[14] evaluated the in vitro effect of various obturating materials on fracture resistance of root canal treated teeth such as gutta-percha/AH Plus, Resilon-epiphany and gutta-percha/zinc oxide eugenol based root canal sealer. They had stated that gutta-percha/AH Plus are more resistant to fracture than those obturated with Resilon-Epiphany, and no statistically significant difference was found between gutta-percha/zinc oxide eugenol and unobturated group.

Lertchirakarn V et al (2011)[47] evaluated the vertical fracture resistance of maxillary central incisors filled with different root canal filling materials such as gutta-percha/AH Plus, gutta-percha/RealSeal sealer, RealSeal cone/RealSeal sealer and RealSeal cone/AH Plus root canal sealer. They had concluded fracture resistance of roots filled using a synthetic polymeric material was lower than for roots filled using gutta-percha. This can be explained by more efficient transmission of forces within the canal space, rather than an inherent ‘reinforcing’ ability of root filling materials.

Monteiro et al (2011)[52] evaluated fracture resistance of root obturated with Resilon or gutta-percha. They had obturated extracted human mandibular single rooted premolar with gutta-percha with AH Plus root canal sealer and Resilon (RealSeal System). They had found that teeth obturated with Resilon were more resistant to fracture than those obturated with; so concluded that Resilon increases the resistance to fracture of single rooted teeth in vitro.

Ulusoy OI et al (2011)[89] compared the effects of different root canal sealers on fracture resistance of simulated immature teeth. They had obturated the root canals with different materials such as, AH Plus-gutta-percha, EndoRez-gutta-percha, EndoRez-Resilon, Hybrid Root Seal-gutta-percha, Hybrid Root Seal-Resilon, iRoot SP-gutta-percha, iRoot SP-Resilon, No obturation other than MTA barrier, No instrumentation, no obturation. They concluded that Hybrid Root Seal (self etching 4-META based) and iRoot SP (calcium silicate-zirconia oxide based) reinforce the simulated immature root against fracture when used with either gutta-percha or Resilon.

Tanalp J et al (2012)[81] compared the fracture resistance of immature teeth treated with MTA along with root canal obturation methods using AH-Plus, MetaSEAL, MTA Fillapex based root canal sealers with lateral compaction technique and quartz fibre posts. They had concluded that teeth filled with quartz fibre post showed highest fracture resistance followed by gutta percha/AH Plus, gutta percha/MetaSEAL and least for gutta percha/MTA Fillapex root canal sealer.

Bhat SS et al (2012)[8] compared the ex vivo effect of different root canal sealer on the fracture resistance of endodontically treated teeth. In this study they obturated the root canal samples with Roekoseal-gutta percha, AH Plus-gutta percha, Pulpdent root canal sealer-gutta percha and zinc oxide eugenol root canal sealer-gutta percha. They had stated that both the resin based sealer used in this study were equally effective compared to zinc oxide based root canal sealer.

Ersev H et al (2012)[25] assessed the influence of MetaSEAL and AH Plus on the resistance to vertical root fracture of endodontically treated teeth when either the matched-taper single cone or lateral condensation technique was used. In this study after preparing the root canals of single rooted teeth upto Protaper F3; these were obturated with AH Plus used with the matched-taper single cone and lateral condensation techniques and in other group MetaSEAL used with matched-taper single cone and lateral condensation techniques then subjected to fracture loading. They had stated that the matched-taper single cone technique along with MetaSEAL and AH Plus has the potential to reinforce endodontically treated teeth.

Milani AS et al (2012)[51] evaluated the reinforcing effect of mineral trioxide aggregate (MTA) and calcium enriched mixture cement (CEM) in simulated immature teeth. In this study they had prepared human maxillary incisors and then in two groups; samples were filled with MTA, calcium enriched mixture completely and in remaining groups MTA plug of 5 mm apical plug was placed and the remainder of canal were filled with composite resin, and then loaded for fracture testing after 6 months. They had concluded after six months, MTA and calcium enriched cement exhibit distinct reinforcing effect on immature teeth.

Nagpal A et al (2012)[54] evaluated the vertical root fracture resistance of endodontically treated teeth obturated with gutta percha-Tubliseal, gutta percha- AH Plus, Resilon cone-Epiphany SE sealer. They had concluded that Resilon cone-Epiphany SE sealer demonstrated highest fracture resistance values than the other materials tested and intact tooth had highest resistance against vertical root fracture.

Sagsen B et al (2012)[61] compared the fracture resistance of roots filled with gutta percha and different root canal sealers such as iRoot SP and Fillapex (Calcium silicate based) and AH Plus (epoxy resin based). They had stated that there was no significant difference found between any sealers; concluding that all sealer used in the study increases the fracture resistance of all instrumented root canals.

Sahebi S et al (2012)[63] compared the short-term effect of calcium hydroxide, Mineral trioxide aggregate (MTA) and calcium enriched mixture cement (CEM) on the strength of bovine root dentin. They had concluded that MTA and CEM cement decreased the flexural strength of bovine root dentin, like their counterpart calcium hydroxide.

Zamin C et al (2012)[101] assessed the influence of cervical preparation on fracture susceptibility of roots filled with different materials such as Endofill-gutta percha, AH Plus-gutta percha and Resilon-Epiphany sealer. They had shown that group with unobturated root showed grater fracture resistance as compared to other filled test group.

Ashraf H et al (2013)[5] compared fracture resistance of teeth filled with gutta percha, and Resilon using two different techniques where they had prepared canal with hand K file and race rotary file and obturated with gutta percha/AH Plus and Resilon/epiphany root canal sealer. They stated that filled root canal filling using Resilon may increase the fracture resistance of treated teeth.

Forghani M et al (2013)[27] evaluated the effect of mineral trioxide aggregate and Portland cement on fracture resistance of dentin. They had depicted that the fracture resistance of MTA treated specimens significantly increased between 2 and 12 weeks. After 12 weeks, mineral trioxide aggregate treated specimens had highest fracture resistance and in the Portland cement group, the fracture resistance of specimens did not change significantly over time.

Topcuoglu HS et al (2013)[87] evaluated the fracture resistance of teeth filled with 3 different endodontic sealers such as gutta percha with epoxy resin-based sealer, mineral trioxide aggregate based sealer based root canal sealer and bioceramic sealer. They had concluded that teeth filled with epoxy resin sealer and bioceramic sealer showed highest fracture resistance compared to teeth filled with mineral trioxide aggregate-based sealer.

El-Ma'aita AM et al (2014)[23] investigated the effect of MTA and gutta percha root canal sealer root canal fillings on the resistance to vertical root root fracture over different storage time intervals i.e. 48 hours, 1 and 6 months at 37°C in synthetic tissue fluid. They had concluded that MTA increases the resistance against vertical root fracture of endodontically treated teeth and influences the mode of fracture after 1 and 6 month of storage in STF compared with gutta-percha and sealer.

II – PUSH-OUT BOND STRENGTH.

Denehy GE and Torney DL (1976)[21] studied internal enamel reinforcement through micromechanical bonding. The internal acid-etch technique is not proposed as the answer to all problems relating to unsupported enamel. It is, however, one useful method of conservative treatment when the proper situation arises. Rather than the extensive removal of undermined enamel in anterior restorations, interior enamel reinforcement through acid-etch bonding deserves consideration. So the adhesive materials reinforce the dental structure due to its property of chemical bonding with the tooth structure.

Kataoka H et al (2000)[39] studied a dentin bonding system suitable for root canal treatment using a newly developed root canal sealer, and to examine its sealing ability. The sealer was composed of vinylidene fluoride/ hexafluoropropylene copolymer, methyl methacrylate, zirconia and tributylborane catalyst and the effect on dentin bonding were studied tensile bond strength testing and scanning electron microscopy. They concluded that tensile bond strength and SEM observation indicates that this new resin root canal sealer has many useful properties desirable for root canal filling material, such as adhesiveness to dentin and gutta percha, as well as good sealing ability.

Lee et al (2002)[45] studied adhesion of endodontic sealers to dentin and gutta percha and interaction with the wall of the root canal and filling material using Zinc oxide eugenol-Kerr, epoxy resin based-AH 26, calcium hydroxide-Sealapex and glass ionomer sealer-Ketac-Endo based root canal sealer. His results indicated that sealants bond strength to dentin showed significant difference between AH 26, Ketac-Endo and Sealapex, Kerr. AH 26 gave significant highest bond strength to gutta percha as compared to remaining groups.

Teixiera F B et al (2004)[82] in their review article stated after an effective microbial control phase, an adequate canal and coronal filling will guarantee a high probability of success. Gutta percha has for many years been widely used as a solid material in root fillings associated with different types of sealers though this material it is not capable of preventing leakage. In fact, because of gutta-percha's limitations, the seal of a coronal restoration may be as important as the gutta percha fill in preventing reinfection of the root canal. Although sealers can form close adhesion to the root canal wall, none is able to bond to the gutta percha core material. Upon setting, the sealer pulls away from the gutta percha core, leaving a gap through which bacteria may pass. So they had described a new thermoplastic, synthetic polyester based root canal filling material, with handling characteristic like gutta percha and used in the same manner as most bonding systems along with self-etch primer. Then it bonds to the primer and to the resin core material; thus, a "monoblock" is formed without the gaps typical in gutta-percha fillings.

Skidmore L J et al (2006)[74] compared the micro push out bond strength of Resilon to that of gutta percha on extracted human anterior teeth. In this study they obturated canals with gutta percha-Kerr Pulp Canal Sealer EWT and Resilon Epiphany primer and root canal sealant. They concluded that mean bond strength of root canal dentin was significantly higher in the Resilon-Epiphany group as compared to gutta percha-Kerr Pulp Canal Sealer EWT group.

Ureyen Kaya B et al (2008)[91] compared the interfacial strength and failure mode of root fillings consisting of different technique material combinations. In this study they had obturated the root canals with gutta percha along with AH Plus, Ketac-Endo or Epiphany using cold lateral compaction or System B with Obtura II. Three serial 1.00 ± 0.05-mm-thick root slices were prepared and push-out tests on the filling material were performed. They had concluded that the push out bond strengths of Resilon/Epiphany combinations were lower than those of gutta percha/conventional root canal sealer combinations. Core materials and sealers may affect the push out bond strengths of root canal filling materials.

Huffman B P et al (2009)[32] examined dislocation resistance of ProRoot Endo sealer-calcium silicate based, Pulp canal sealer-zinc oxide eugenol based sealer and AH Plus jet –epoxy resin based root canal sealers from radicular dentine with and without immersion in simulated body fluid. They concluded that under ideal cleaning and shaping conditions, the dislocation resistance of ProRoot Endo Sealer, AH Plus jet and Pulp canal sealer are independent of the location of the radicular dentine; both ProRoot Endo sealer and AH Plus jet exhibited higher dislocation resistance after immersion in simulated body fluid.

Jainaen A et al (2009)[34] evaluated the effect of two resin based sealer cements are able to strengthen root dentine, as measured by work of fracture, micro-push shear strength and resistance to vertical fracture. They had assigned the study sample of extracted human single rooted teeth according to intact, root canal prepared but unfilled or root filled with epoxy resin based sealer i.e. AH Plus Jet-gutta percha and urethane dimethacrylate based sealer i.e. RealSeal cone(Resilon)-RealSeal sealer. The result had showed that neither epoxy nor UDMA based root canal sealer enhanced the fracture resistance when placed within root canals of extracted tooth.

Rahimi M et al (2009)[56] compared the micro shear bond strength of three resin-based sealers such as AH Plus, RealSeal, and EndoREZ to root dentin and assessed whether sealer cements behave differently in thin and thick films. They had stated that the epoxy resin-based sealer had the highest micro shear bond strength to root dentin compared with urethane dimethacrylate-based sealer. Bond strengths for the thick sealer group were significantly higher than the thin sealer group and may reflect different patterns of behaviour when the sealer is present as a thin layer.

Ersahan S and Aydin C (2010)[24] evaluated the push-out bond strength of iRoot SP and compare it with other widely used root canal sealers. Bond strengths of AH Plus and iRoot SP were significantly higher than those of EndoREZ and Sealapex. They found no significant difference between the bond strength of iRoot SP and AH Plus ($p = 0.274$).

Sagsen B et al (2011)[62] assessed the push-out bond strength of two new calcium silicate-based endodontic sealers in the root canals of extracted teeth here canals were filled with AH Plus-gutta percha, iRoot SP-gutta percha and Fillapex-gutta percha; then push out strength was measured. They concluded that the iRoot SP and AH Plus group had showed significantly higher bond strength values than the MTA Fillapex.

Nagas E et al (2012)[53] evaluated the effects of intraradicular moisture conditions on the push-out bond strength of root canal sealers. In this study to the moisture condition tested were as; (1) ethanol (dry): excess distilled water was removed with paper points followed by dehydration with 95% ethanol, (2) paper points: the canals were blot dried with paper points with the last one appearing dry, (3) moist: the canals were dried with low vacuum by using a Luer adapter for 5 seconds followed by 1 paper point for 1 second, and (4) wet: the canals remained totally flooded. And then canals were filled with gutta-percha-AH Plus, iRoot SP, MTA Fillapex root canal sealers and Resilon-Epiphany. They had showed that irrespective of the moisture conditions, iRoot SP displayed the highest bond strength to root dentin. The sealers displayed their highest and lowest bond strengths under moist (3) and wet (4) conditions, respectively. The degree of residual moisture significantly affects the adhesion of root canal sealers to radicular dentin. For the tested sealers, it may be advantageous to leave canals slightly moist before filling.

Amin SW et al (2012)[2] investigated the effect of prior calcium hydroxide intracanal placement on the bond strength of epoxy resin i.e. AH Plus and two calcium silicate based root canal sealer i.e. iRoot SP, and MTA Fillapex. In this study after biomechanical preparation; first group was obturated without exposure of calcium hydroxide while in other study groups canals were filled with calcium hydroxide for 7 days and then calcium hydroxide was removed by irrigation and canals were obturated with gutta percha -AH Plus, iRoot SP and MTA Fillapex root canal sealer. Horizontal root sections of 2 mm thickness were made from middle part of root to evaluate push out bond strength of sealer with dentine. The results had stated that AH Plus showed a higher bond strength than iRoot SP and MTA Fillapex in the control group i.e. without the calcium hydroxide exposure and prior calcium hydroxide placement, AH Plus and iRoot SP showed a similar bond strength, which was higher than MTA Fillapex. So they concluded that prior calcium hydroxide placement seemed to improve the dislodgment resistance of iRoot SP and AH Plus but did not affect MTA Fillapex.

Assmann E et al (2012)[6] evaluated the bond strength to root dentin of two mineral trioxide aggregate based sealers (Endo CPM sealer and MTA Fillapex) and of 1 epoxy resin-based sealer (AH Plus sealer). They had showed that Endo CPM sealer presented advantages when a post preparation was required. MTA Fillapex presented acceptable resistance to dislodgement, which was similar to that observed in samples filled with AH Plus sealer.

Vilanova WV et al (2012)[94] assessed the bond strength of Epiphany and AH Plus sealers to root canal walls using a push-out test after use of several endodontic irrigants. In this study they had irrigated the canals with the different irrigation solution such as 1% NaOCl for 30 min; 1% NaOCl for 30 min followed by 17% EDTA for 5 min, 17% EDTA for 30 min, 24% EDTA gel for 30 min) and 2% chlorhexidine gluconate gel for 30 min. and then obturated with gutta percha-AH Plus and Resilon-Epiphany root canal sealer and push out bond strength was measured. They had concluded that except for 1% NaOCl, the removal of smear layer with the other irrigants increased the bond strength of AH Plus to intracanal dentine. The use of 1%

NaOCl for 30 min with 17% EDTA as final irrigant for 5 min increased the bond strength of Epiphany.

Shokouhinejad N et al (2013)[72] compare the bond strength of AH Plus and EndoSequence BC sealer in presence or absence of smear layer. They evaluated no significant difference between gutta-percha/AH Plus and gutta-percha/ EndoSequence in bond strength with no significant effect of presence or absence of smear layer on it. Mode of failure being mainly cohesive for all groups used in the study.

Sonmez IS et al (2013)[76] evaluated the push-out bond strength of MTA Fillapex and compared it with ProRoot MTA and AH Plus root canal sealer. They obturated the root canals of extracted single rooted teeth with gutta percha-MTA Fillapex, gutta percha-AH Plus and in third group entire canal filled with ProRoot MTA. They had reported that ProRoot MTA had the highest bond strength, whilst MTA Fillapex displayed the lowest values among the groups.

Materials and methods

ARMAMENTARIUM (fig no.1 and 2):

1. Fifty five extracted caries free and fracture free, human single rooted mandibular premolar teeth.
2. Diamond disc (Summadisk, Shofu Inc., Japan).
3. Barbed broaches (Spiro Colorinox, DentsplyMaillefer, Switzerland).
4. Digital verniercaliper (Advanced Technocracy Inc., Ambala, India).
5. Straight handpiece (Marathon, SaeyangMicrotech, Korea).
6. Stainless steel K files (No.10, 25mm) (Mani Inc., Japan).
7. Endo gauge (DentsplyMaillefer, Switzerland).
8. Endodontic rotary handpiece (Anthogyr, Dentsply, France).
9. NiTi Rotary files (ProTaper, Dentsply Maillefer).
10. Contra-angle handpiece (NSK Nakanishi Inc., Japan).
11. Hand Plugger (GDC, India).
12. Lentulo spiral (Mani Inc., Japan).
13. Tweezer (GDC, India).
14. Ball burnisher (GDC, India).
15. 5ml syringe (Becton Dickinson, India).
16. 27 Gauge needle (Aman medical, Daman, India).
17. Peizo gas burner (Prince, India).
18. Paper mixing pad.

MATERIALS (fig no.2, 3a and 3b):

1. 0.9 % Normal Saline.
2. 5.25% Sodium Hypochlorite (NaOCl) (Prime Dental Products, Thane).
3. EDTA paste (Avueprep, Dental Avenue, Mumbai, India).
4. Paper points (F3-size) (DentsplyMalliefer).
5. GuttaPercha points (F3-size) (DentsplyMalliefer).
6. Autopolymerizing acrylic resin (DPI RR Cold cure,Mumbai).
7. Temporary restorative material (CAVITEMP, Ammdent, Chandigarh).
8. Copper Rings.
9. Polyvinylsiloxane impression material (Aquasil Ultra Heavy, Denstply).
10. Gloves and plastic bowl.

EQUIPMENTS (fig no.16 and 22)

11. Ultrasonic scaler (Cavitron Bobcat Pro, New York, USA).
12. Universal testing machine (Instron Corp, Canton, MA).
13. Optical stereomicroscope (SteREO Discovery V8, Zeiss Germany).
14. Radio Visio Graphy. (Suni Plus, San Jose ,CA, USA).

Experimental materials: (fig no.4, 5 and 6)

Endodontic Sealer	Composition	Manufacturer
Endosequence BC	Zirconium oxide, calcium silicates, calcium phosphate monobasic, calcium hydroxide, filler and thickening agents	Brasseler USA (Savannah, GA)
MTA Fillapex	Paste/paste system: resins (salicylate, diluting, natural), radiopaque bismuth, nanoparticulated silica, mineral trioxide aggregate, pigments.	Angelus (Londrina, Brazil)
AH Plus Jet	Paste A: diepoxide, calcium tungstate, zirconium oxide, silica, iron oxide pigments. Paste B: 1-adamantane amine, N,N-dibenzyl-5-oxa-nonandiamine-1,9, TCD diamine, calcium tungstate, zirconium oxide, aerosil silica, silicone oil	Dentsply De Trey, (Konstanz, Germany)

Methods

Selection of Teeth

Fifty five extracted caries-free and visually assessed fracture-free, human single rooted mandibular premolar teeth were selected for the study **(fig no.1)**. Teeth were cleaned of calculus, deposits and soft tissue debris with ultrasonic scaler **(fig no.9).**

The radiographs of all the teeth were taken with Radio Visio Graphy unit. Two radiographs were taken, one in a bucco-lingual **(fig no.7)** and the other in a mesio-distal plane **(fig no.8)** for studying the root canal anatomy. These radiographs were performed to collectively select curved root canal of 0 to 10 degree using Schneider's method, to confirm that each tooth had a single canal, no previous root canal treatment and no resorption. The teeth were stored in 0.9% normal saline solution for twenty four hours.

Sample preparation

Fifty five teeth were sectioned with a diamond disc and straight handpiece under constant irrigation of saline by syringe needle **(fig no.11)**, 1mm coronal to the cemento-enamel junction, measuring root specimens of 14 mm in length using digital verniercaliper **(fig no.10)**.The Buccolingual and mesiodistal diameters of the coronal section were measured by digital caliper and all roots were of similar dimensions measuring 4.82 ± 0.6 mm mesiodistally and 5.33 ± 0.5 mm buccolingually. The pulpal tissue was removed using barbed broach. The patency of the canal was checked with a No. 10 K file. The working length was determined visually by subtracting 1mm from the length of a size 10K file at the apical foramen **(fig no.12)**. The root canals were instrumented with crown down technique with endodontic rotary handpiece and NiTi rotary file i.e. Protaper Rotary instruments. Fifty teeth were instrumented up to a master apical size of F3 with protaperrotary instruments by using a 64:1 reduction handpeice **(fig no.13)**.

A root canal lubricant (Avueprep, Dental Avenue, Mumbai, India) was used throughout the cleaning and shaping of the root canal. Throughout instrumentation, irrigation was performed using 1 ml of 5.25% sodium hypochlorite and with 1 ml of 17% EDTA alternatively to remove smear layer. The canals were recapitulated with a No. 10 K file to ensure patency of the canal terminus. Final irrigation was done by 10 ml of saline to remove any remaining sodium hypochlorite residue with a 27-gauge needle. The root canals were dried using sterile paper points.

I - FRACTURE RESISTANCE

Thirty (out of 45) prepared and obturated teeth were randomly divided into three experimental groups of 10 teeth each.

GROUP-I (n = 5)	Negative control group - unprepared and unfilled.
GROUP-II (n = 5)	Positive control group – prepared and unfilled.
GROUP-III (n = 10)	Experimental group – canals obturated with gutta-percha and Endosequence BC sealer.
GROU-IV (n = 10)	Experimental group – canals obturated with gutta-percha and MTA Fillapex sealer.
GROUP-V (n = 10)	Experimental group – canals obturated with gutta-percha and AH-Plus Jet sealer.

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Group-1: (Negative control)

In this group; root canals were left uninstrumented and unobturated.

Group-2: (Positive control)

In this group; root canals were instrumented but not obturated.

Group-3:

(Canals obturated with gutta-percha and Endosequence BC sealer).

Endosequence BC sealer were introduced into the root canal via its intracanal delivery tip. The tip was not inserted deeper into canal than the coronal third. An F3 master matched taper gutta-percha cone (Dentsply Malleifer) with good tug back were then coated with sealer and slowly inserted until the working length reached into the canal.

Group-4:

(**Canals obturated with gutta-percha and MTA Fillapex sealer.)**

MTA Fillapex sealer were mixed according to the manufacturer's instruction and introduced into the root canal by using a lentulo-spiral. An F3 master matched taper gutta-percha cone (Dentsply Malleifer) with good tug back were then coated with sealer and slowly inserted until the working length reached into the canal.

Group-5:

(**Canals obturated with gutta-percha and AH-PLUS Jet sealer.)**

AH Plus Jet sealer were introduced into the root canal via its intraoral delivery tip. An F3 master matched taper gutta-percha cone (Dentsply Malleifer) with good tug back were then coated with sealer and slowly inserted until the working length reached into the canal.

Buccolingual and mesiodistal radiographs were taken to confirm proper and complete obturation. After obturation, the coronal 1mm of filling materials were removed and spaces were filled with a temporary filling material.

Storage of samples:

All samples were stored in 100 % humidity at 37^{o}C for two weeks in incubator to simulate *in vivo* conditions ensuring correct and complete setting of sealing material.

Mounting of the samples:

After two weeks, preparation of the root specimens was done for mechanical testing.

The entire specimen were mounted vertically in self curing acrylic resin blocks in a copper rings (height = 20 mm, diameter = 20 mm). Specimen were mounted in acrylic resin keeping 9mm of root exposed and 4-5 mm of root was embedded in resin **(fig no.15)**. To simulate a periodontal membrane, apical 5mm of all roots were covered with polyvinylsiloxane impression material and then mounted. Then resin block samples were removed from the copper ring when the first sign of polymerization occurred.

The temporary material (Cavitemp) was removed and the root canal specimen were subjected to compression loading.

Preparation for Mechanical Testing:

The blocks were mounted with the vertically aligned roots in the testing machine one at a time **(fig no.16).** Each acrylic blocks were placed on lower plate of the testing machine.

A loading plunger with a spherical tip of 3mm in diameter were mounted in upper plate and aligned with the center of the canal opening of each specimen. Each specimen was subjected to a load at a crosshead speed of 1.0 mm/min until the root fractured. This is the point at which a sharp and instantaneous drop greater than 25% of the applied load was observed. The test was terminated at this point and the force required to fracture the specimen were recorded in Newton's (N).

II - PUSH OUT BOND STRENGTH.

After 2 weeks of storage, the roots were sectioned perpendicular to its canal into 1mm thick slice by using water cooled precision saw. Two section were obtained at a thickness of 1mm ± 0.1 in the coronal part of each root **(fig no.19)**. The diameter of filling of each slice were measured with a digital calliper in cervical and apical aspects of slice.

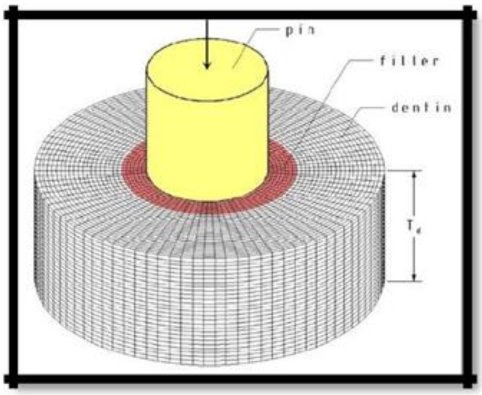
GROUP-I (n = 10)	Thin slice of 1mm of root canals obturated with Endosequence BC sealer and gutta-percha were obtained.
GROUP-II (n = 10)	Thin slice of 1mm of root canals obturated with MTA Fillapex sealer and gutta-percha were obtained.
GROUP-III (n = 10)	Thin slice of 1mm of root canals obturated with AH-PLUS Jet sealer and gutta-percha were obtained.

Preparation for Mechanical Testing:

Each slice were marked on its apical side and positioned facing upward towards plunger tip on a acrylic block, with central hole, hold by lower plate of universal testing machine (Instron Corp, Canton, MA) push-out test. Root filling in each slice were subjected to loading using a testing machine that carried a 1mm in diameter cylindrical plunger **(fig no.20)**.

During loading, plunger contact only the root filling and loading speed were set at 1mm/min^{-1} from apical to coronal direction until the bond failure occurred. The values for each specimen at the time of dislodgement were recorded in Newton's (N).

SCHEMATIC REPRESENTATION OF PUSH-OUT TEST.



The bond strength at dislodgement was calculated in megapascals (MPa) by dividing the load in newtons (N) by the interface bonded area. The bonded area of each slice was calculated using the following formula:

$$\textbf{area} = \mathbf{2\pi r \times h}$$

where $\pi = 3.14$, r = radius of the intra-radicular space, and h = height of section in mm.

For e.g.: For specimen 1 of group 1 (r=1mm, h=1mm) value in Newton's (N) is 10.23N.

So value in Megapascal can be calculated as:

$$\frac{\textit{load in newton}}{\textit{bonded area}} = \frac{10.23}{2\pi rh} = \frac{10.23}{6.28} = 1.63\text{MPa}.$$

(r=1mm, h=1mm, π=3.14)

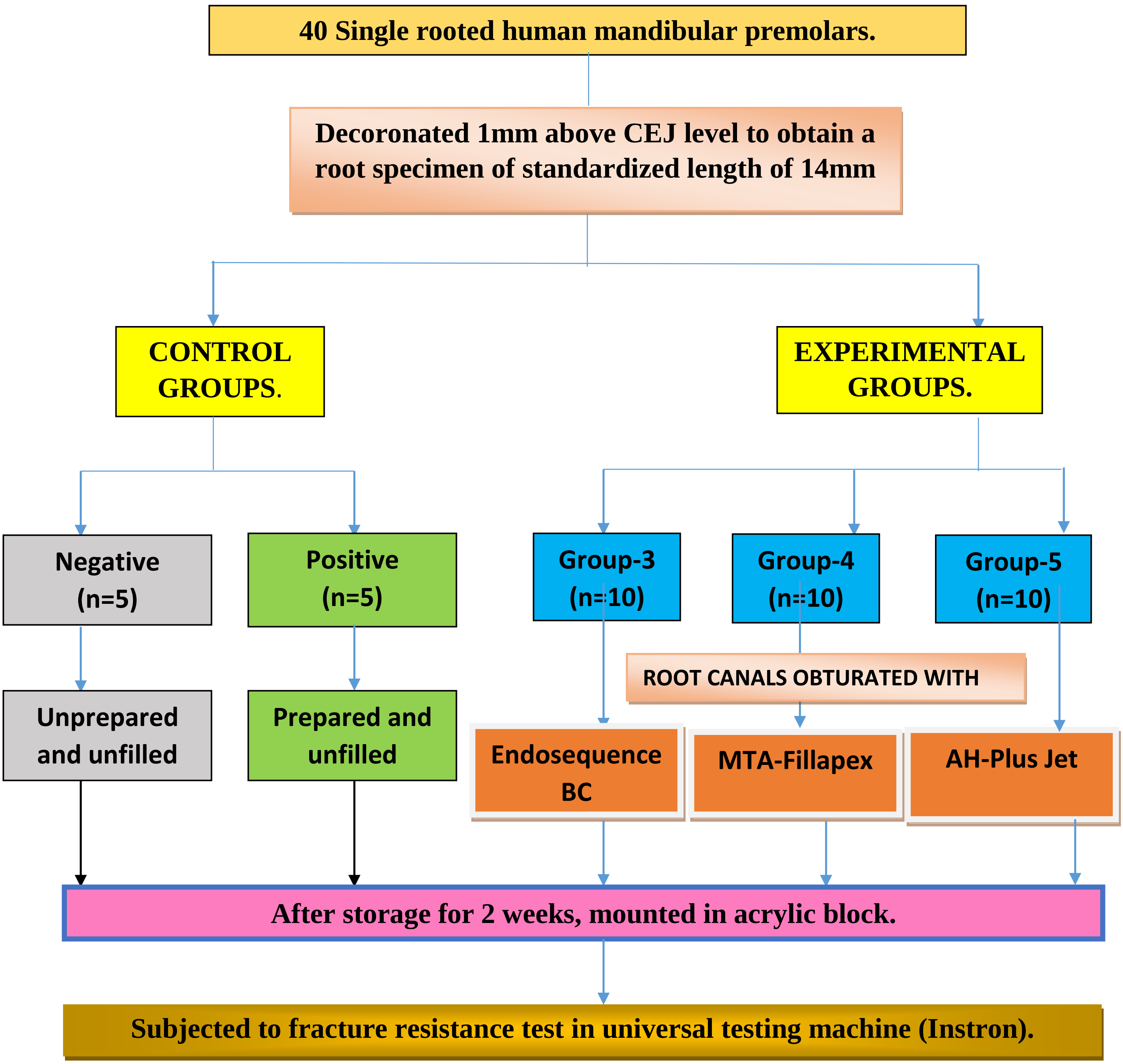
Analysis of failure modes:

The failure modes were examined and analysed under a optical stereomicroscope at 30X magnification. Modes of failure were considered as follows: (1) adhesive, at filling material-dentin interface; **(fig no.25)** (2) cohesive, within filling material; **(fig no.23)** and (3) mixed failure **(fig no.24).**

STATISTICAL ANALYSIS:

The statistical analysis was performed using a commercially available software program SPSS version 16.0.0.

FOR FRACTURE RESISTANCE



FOR PUSHOUT BOND STRENGTH

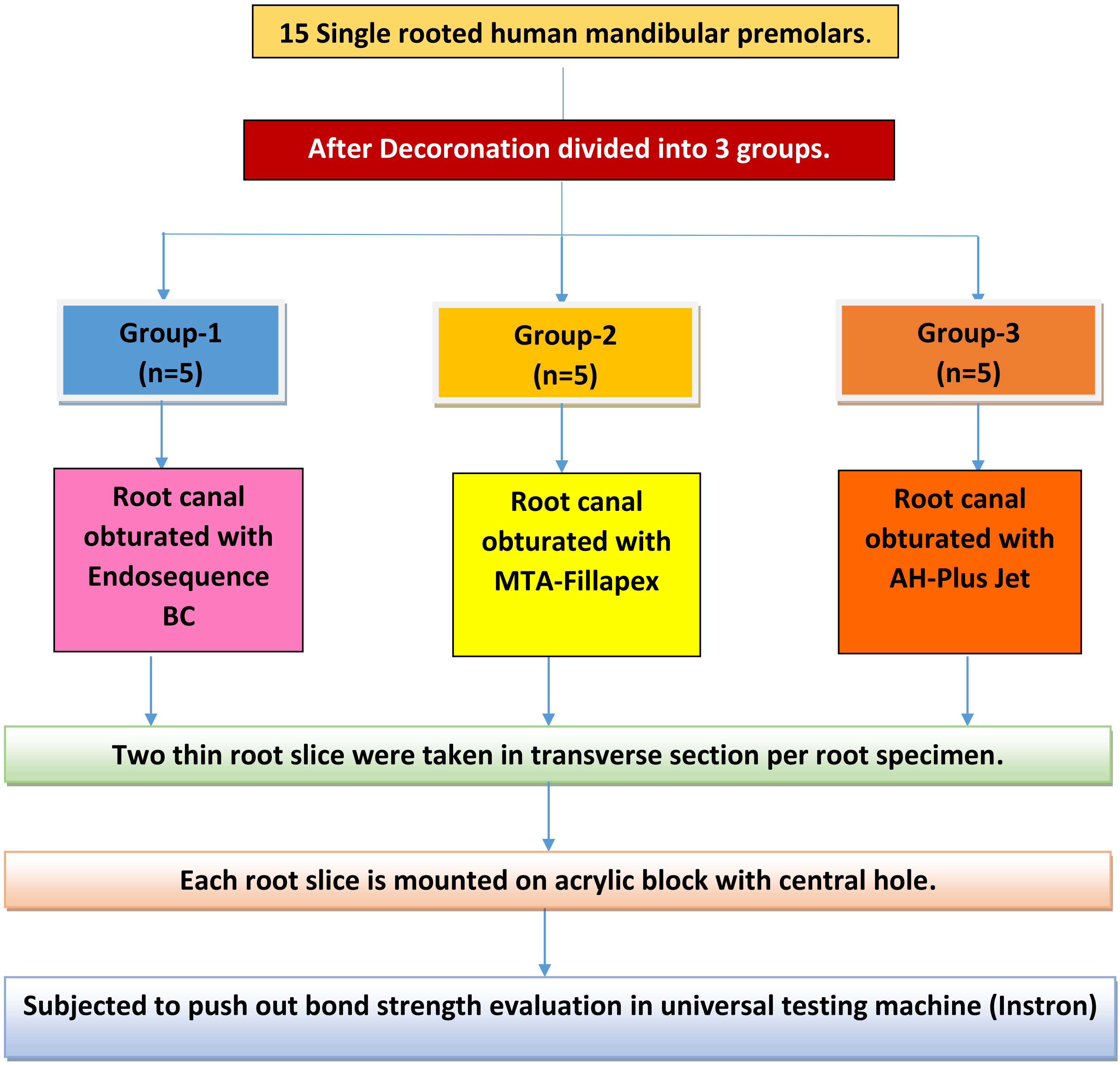


Fig no-1: **Extracted human single rooted mandibular premolars.**

Fig no-2: Armamentarium used in the study.

Fig no-3a: Copper rings.

Fig no-3b: Acrylic resin.

Fig no-4: <u>Endosequence BC sealer.</u>

Fig no-5: <u>MTA Fillapex sealer.</u>

Fig no-6: AH Plus Jet sealer.

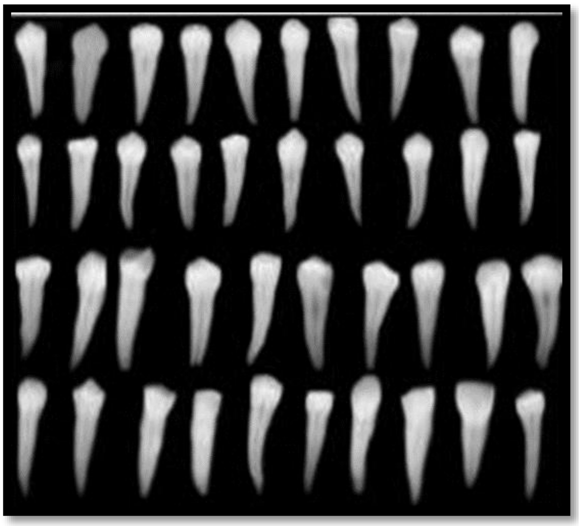


Fig no-7: Bucco-lingual RVG image.

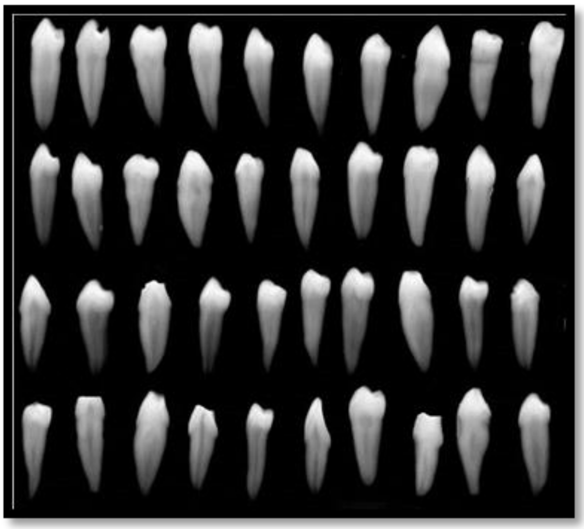
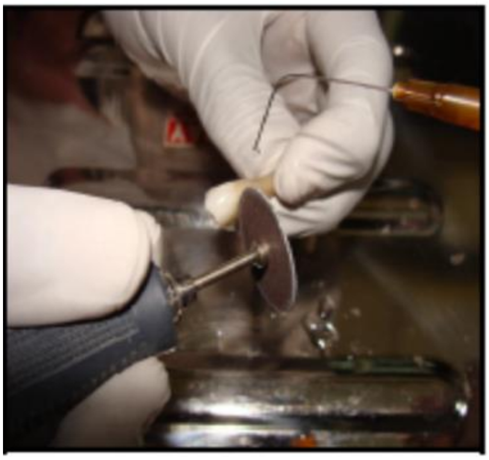


Fig no-8: Mesio-distal RVG image.

Fig no-9: Cleaning of teeth with ultrasonic scaler.

Fig no-10: Measurement of teeth.



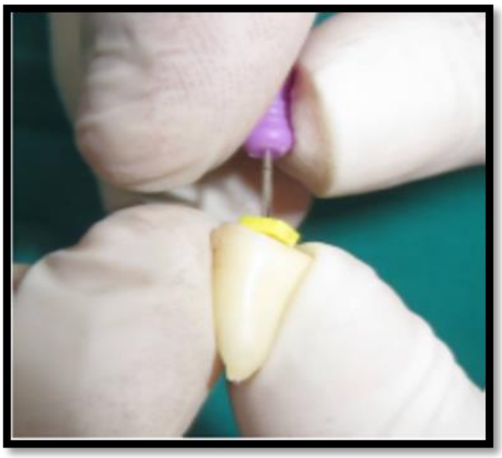


Fig no-11: Decoronation of teeth.

Fig no-12: working length determination

Fig no-13: Biomechanical preparation by using rotary.

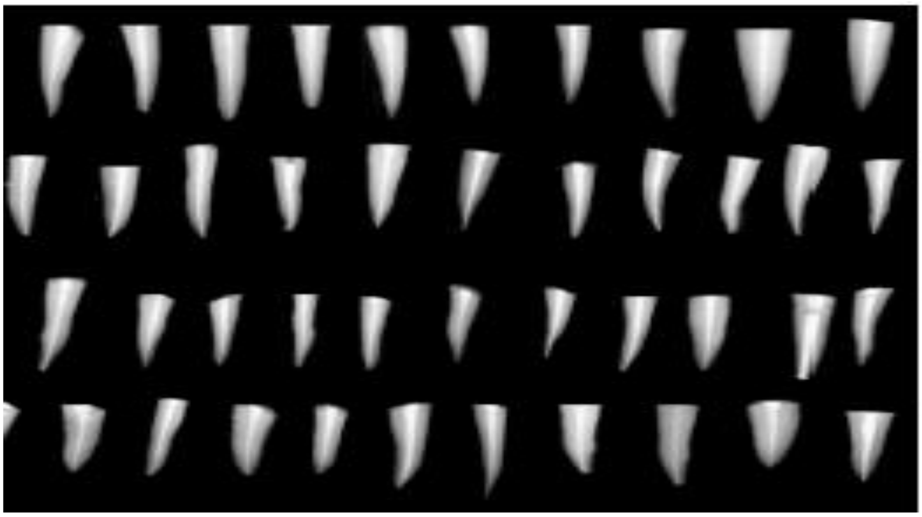


Fig no-14: RVG images after obturation.

Fig no-15: Decoronated roots mounted in acrylic resin blocks.

Fig no-16: Universal testing machine. (Instron)

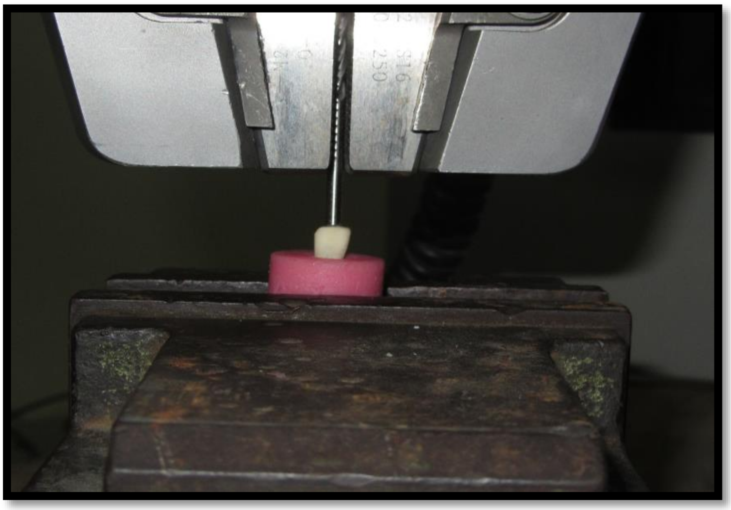


Fig no-17: Mounted acrylic block on lower plate of universal testing machine.

Fig no-18: Fractured root specimens under compression.

Fig no-19: Root slice 1mm in thickness.

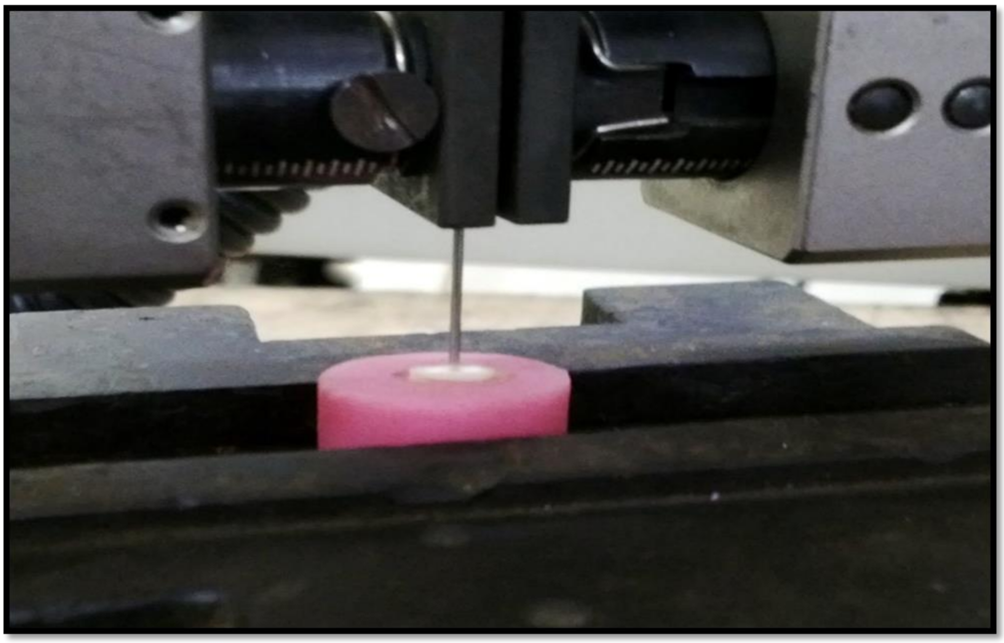


Fig no-20: Push-out bond strength evaluation of slice mounted on lower segment of universal testing machine.

Fig no-21: Debonded surface of root slice specimen after push-out test.

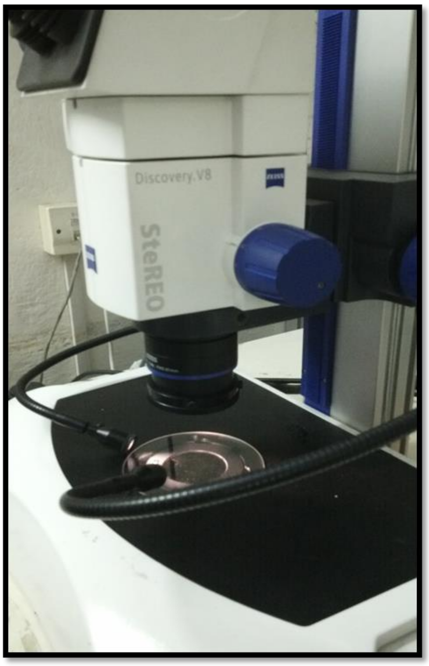


Fig no-22: Optical Stereomicroscope.

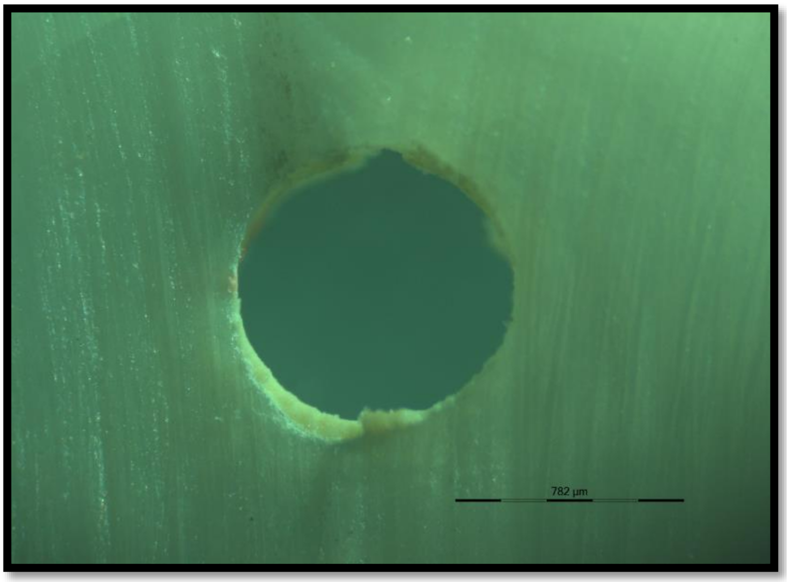


Fig no-23: Cohesive mode of failure.

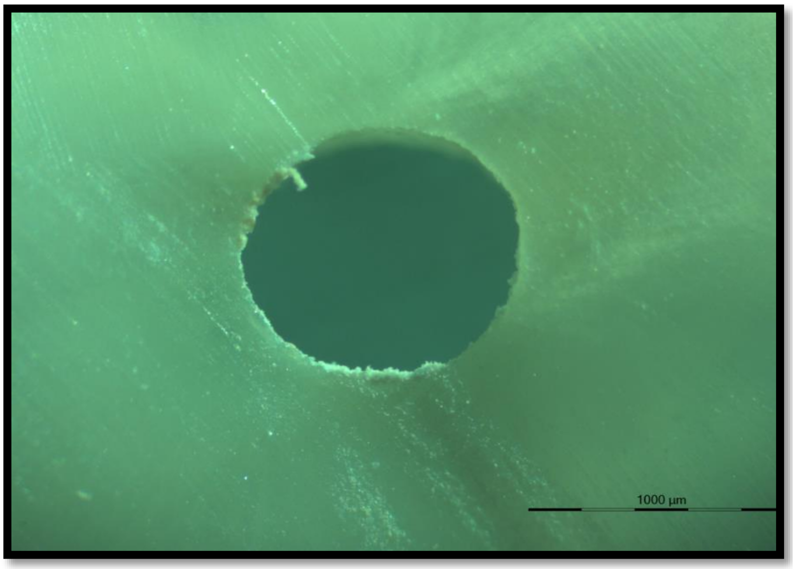


Fig no-24: Mixed mode of failure.

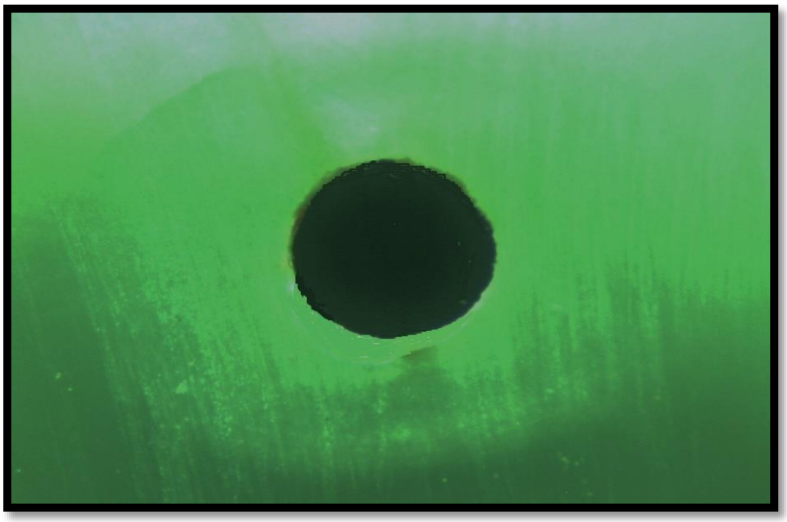


Fig no-25: Adhesive mode of failure.

Results

Table -1 Fracture resistance values in Newton's (N).

Group – 1 **NEGATIVE GROUP**	Group – 2 **POSITIVE GROUP**	Group – 3 **ENDOSEQUENCE-BC**	Group – 4 **MTA-FILLAPEX**	Group – 5 **AH-PLUS JET**
433.16	261.14	576.18	356.19	546.16
578.23	317.2	356.29	410.2	376.09
454.13	333.14	424.31	420.18	396.19
386.06	367.03	454.29	469.19	434.28
509.16	401.07	404.19	450.11	474.29
		512.28	438.17	526.19
		522.21	444.11	505.18
		534.19	390.1	454.2
		556.2	386.14	414.21
		386.19	368.1	494.13

Table-2A/B One-way Analysis Of Variance (ANOVA) test for Fracture resistance.

	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
					Lower Bound	Upper Bound		
Negative Group	5	472.148	73.9579	33.07502	380.3170	563.979	386.06	578.23
Positive Group	5	335.916	52.8265	23.62474	270.3232	401.508	261.14	401.07
Endosequence BC	10	472.633	77.3797	24.46961	417.2789	527.987	356.29	576.18
MTA-Fillapex	10	413.249	37.5408	11.87147	386.3939	440.104	356.19	469.19
AH-Plus Jet	10	462.092	56.8386	17.97396	421.4321	502.751	376.09	546.16
Total	40	438.001	73.4761	11.61759	414.5027	461.500	261.14	578.23

ANOVA
(B)

Values

	Sum of Squares	Df	Mean Square	F	Sig.
Between Groups	81860.956	4	20465.23	5.566	.001
Within Groups	128689.800	35	3676.85		
Total	210550.756	39			

Table-3 Post Hoc Tukey test for multiple comparison among the groups for Fracture resistance.

(I) Groups	(J) Groups	Mean Difference (IJ)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
Negative Group	**Positive Group**	136.23200*	38.35024	.009	25.9728	246.4912
	Endosequence	-.48500	33.21228	1.000	-95.9723	95.0023
	MTA-Fillapex	58.89900	33.21228	.405	-36.5883	154.3863
	AH-Plus Jet	10.05600	33.21228	.998	-85.4313	105.5433
Positive Group	**Negative Group**	-136.23200*	38.35024	.009	-246.4912	-25.9728
	Endosequence	-136.71700*	33.21228	.002	-232.2043	-41.2297
	MTA-Fillapex	-77.33300	33.21228	.160	-172.8203	18.1543
	AH-Plus Jet	-126.17600*	33.21228	.005	-221.6633	-30.6887
Endosequence	**Negative Group**	.48500	33.21228	1.000	-95.0023	95.9723
	Positive Group	136.71700*	33.21228	.002	41.2297	232.2043
	MTA-Fillapex	59.38400	27.11771	.207	-18.5811	137.3491
	AH-Plus Jet	10.54100	27.11771	.995	-67.4241	88.5061
MTA-Fillapex	**Negative Group**	-58.89900	33.21228	.405	-154.3863	36.5883
	Positive Group	77.33300 -	33.21228	.160	-18.1543	172.8203
	Endosequence	59.38400	27.11771	.207	-137.3491	18.5811
	AH-Plus Jet	-48.84300	27.11771	.389	-126.8081	29.1221
AH-Plus Jet	**Negative Group**	-10.05600	33.21228	.998	-105.5433	85.4313
	Positive Group	126.17600*	33.21228	.005	30.6887	221.6633
	Endosequence	-10.54100	27.11771	.995	-88.5061	67.4241
	MTA-Fillapex	48.84300	27.11771	.389	-29.1221	126.8081

*. The mean difference is significant at the 0.05 level.

Table-4 Push-out bond strength values in Newton's (N)

	GROUP -1 ENDOSEQUENCE BC.	GROUP- 2 MTA FILLAPEX.	GROUP-3 AH-PLUS JET.
1	10.23	11.36	14.94
2	11.74	6.46	10.48
3	14	7.34	10.73
4	9.85	11.36	14.06
5	10.11	11.80	10.23
6	9.35	7.09	14.88
7	11.49	7.59	9.48
8	11.17	8.35	10.67
9	14.25	10.23	11.36
10	10.23	7.59	14.91

Table-5 Push-out bond strength values in Megapascal's (MPa)

	GROUP -1 ENDOSEQUENCE BC.	GROUP- 2 MTA FILLAPEX.	GROUP-3 AH-PLUS JET.
1	1.63	1.81	2.38
2	1.87	1.03	1.67
3	2.23	1.17	1.71
4	1.57	1.81	2.24
5	1.61	1.88	1.63
6	1.49	1.13	2.37
7	1.83	1.21	1.51
8	1.78	1.33	1.7
9	2.27	1.63	1.81
10	1.63	1.21	2.38

Table-6A/B One-way Analysis of Variance (ANOVA) for push-out bond strength test.

	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean Lower Bound	95% Confidence Interval for Mean Upper Bound	Minimum	Maximum
ENDOSEQUENCE BC	10	1.7910	.26959	.08525	1.5981	1.9839	1.49	2.27
MTA FILLAPEX	10	1.4210	.32573	.10300	1.1880	1.6540	1.03	1.88
AH-PLUS JET	10	1.9400	.35643	.11271	1.6850	2.1950	1.51	2.38
Total	30	1.7173	.37968	.06932	1.5756	1.8591	1.03	2.38

ANOVA
(B)

	Sum of Squares	Df	Mean Square	F	Sig.
Between Groups	1.428	2	.714	7.005	.004
	2.752	27	.102		
Total	4.181	29			

Table-7 Post Hoc Tukey test for multiple comparison among the groups for Push-out bond strength.

(I) MEGAPASCALS		Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
ENDOSEQUENCE BC	MTA FILLAPEX	.37000*	.14279	.039	.0160	.7240
	AH-PLUS JET	-.14900	.14279	.557	-.5030	.2050
MTA FILLAPEX	ENDOSEQUENCE BC	-.37000*	.14279	.039	-.7240	-.0160
	AH-PLUS JET	-.51900*	.14279	.003	-.8730	-.1650
AH-PLUS JET	ENDOSEQUENCE BC	.14900	.14279	.557	-.2050	.5030
	MTA FILLAPEX	.51900*	.14279	.003	.1650	.8730

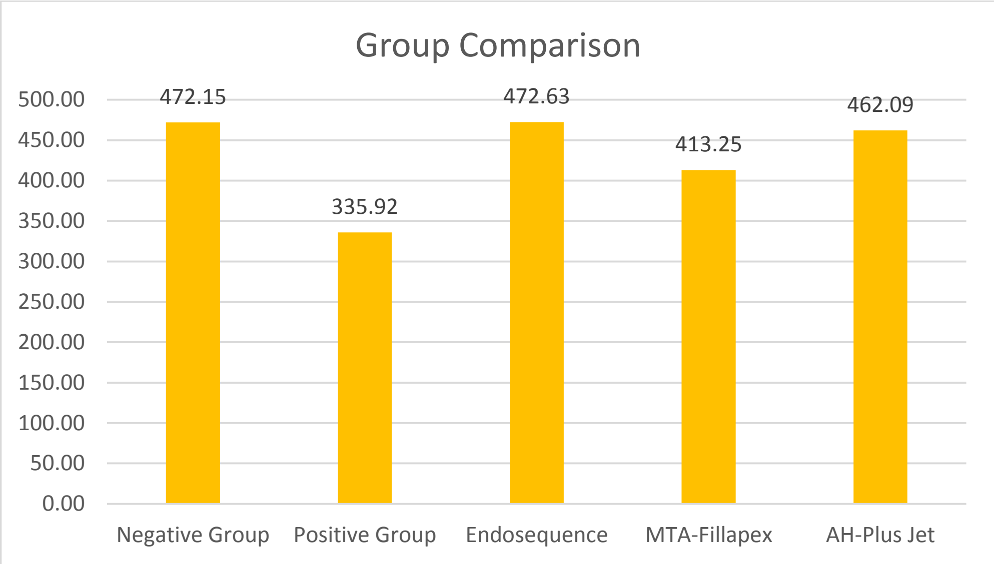
*. The mean difference is significant at the 0.05 level.

Multiple comparison using oneway ANOVA test					
Groups	N	Mean	S.D	F	Sig.
ENDOSEQUENCE BC	10	1.79	0.27	7.005	0.0035 **
MTA FILLAPEX	10	1.42	0.33		
AH-PLUS JET	10	1.94	0.36		
** Highly Sig. at P < .01 level					

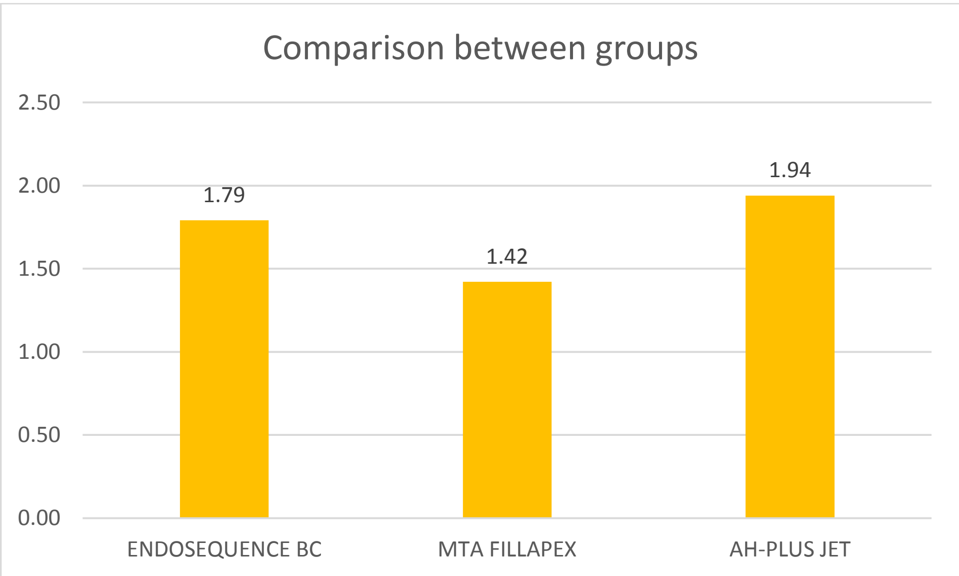
Table-8 Mode of bond failure.

Group	FAILURE MODE		
	ADHESIVE	COHESIVE	MIXED
I (n=10)	-	7	3
II (n=10)	2	6	2
III (n=10)	-	8	2

Graph-1 <u>Shows the group comparison of fracture resistance.</u>



Graph-2 <u>Shows the group comparison for push-out bond strength.</u>



Interpretation of results.

I-FRACTURE RESISTANCE.

Values for fracture resistance for all five groups are presented in Table-1. Means and standard deviations of all three groups ae presented in a Table 2A. To understand whether there is significant difference between the three different sealers the following statistical analysis test were done.

STATISTICAL ANALYSIS:

The collected data was analysed with SPSS 16.0 version. To describe about the data; descriptive statistics mean and S.D were used. The normality test of Shapiro–Wilk and Levene's variance homogeneity test were applied to the data. The data were normally distributed, and there was homogeneity of variance amongst the groups. The fracture resistance data were analysed **by One-way analysis of variance (ANOVA) with the Tukey's HSD post-hoc test,** with significance set at $P < 0.05$.

Result interpretation:

ANOVA test is performed at **95% confidence level** and **39 degree of freedom**. The results that obtained shown in **Table no. 2A and B.**

Result shows that there is significant difference between mean fracture resistances of all the groups except between Endosequence BC group **(GROUP III)** and negative control group **(GROUP I)**.

It can be seen that the calculated value of **F i.e. 5.566** is significant with **p value of 0.001 ($P<0.05$)** which shows that all the five groups differ significantly as far as fracture resistance is considered except between Endosequence BC group and negative control group.

To further test that which group shows significant difference between mean fracture resistance, data were further analysed with Tukey post hoc test for multiple comparison **(Table-3)**. The level of significance was set at $P < .05$.

Amongst the tested group, there is significant difference between **group III (Endosequence BC) and positive group (p=.002), group V (AH-plus Jet) and positive group (p=.005)**. No significant difference exist among experimental groups. A statistical ranking for fracture resistance values was obtained as follows (p=0.05) **Endosequence BC >Ah-Plus Jet > MTA-Fillapex** as shown in **(Graph 1)**.

II - PUSH OUT BOND STRENGTH.

Values for push-out test for all three groups are presented in Table-4 and 5.Means and standard deviations of all three groups are presented in a Table 6A. To understand whether there is significant difference between the three different sealers the following statistical analysis test were done.

STATISTICAL ANALYSIS:

The collected data was analysed with SPSS 16.0 version. To describe about the data; descriptive statistics mean and S.D were used. The normality test of Shapiro–Wilk and Levene’s variance homogeneity test were applied to the data. The data were normally distributed, and there was homogeneity of variance amongst the groups. The push-out data were analysed by One-way analysis of variance (ANOVA) with the Tukey's HSD post-hoc test, with significance set at ($P < 0.05$).

Result interpretation:

ANOVA test were performed at **95% confidence leve**l and **29 degree of freedom**. Result that obtained is shown in **Table no. 6B**. According to result obtained there is significant difference between push-out bond strength between the groups.

It can be seen that the calculated value of **F i.e. 7.004** is significant with **p value of 0.004** ($P<0.05$) which shows that all the three groups differ significantly as far as push-out bond strength is considered.

To further test that which groups shows significant difference between mean push-out bond strength data were further analysed with **Tukey post hoc test** for multiple comparison **(Table 7)**. The level of significance was set at $P < .05$.

There is highly significant difference between **Group III (AH-Plus Jet)** and **Group IV (MTA Fillapex) (p=.003)**, significant difference between **Group I (Endosequence BC)** and **Group II (MTA Fillapex) (p=0.39)** and no difference between **Group I (Endosequence BC) and Group III (AH-Plus Jet) (p=0.557)**. Statistical ranking obtained was as follows (with respect to mean push-out values): **AH-Plus jet > Endosequence BC > MTA Fillapex** as shown in **(Graph -2).**

Mode of failure for all the group were mainly **cohesive** with adhesive failure exist only for **Group II (MTA-Fillapex) (Table-8).**

Discussion

DISCUSSION.

As dental professionals became increasingly aware of the fact that natural teeth function more efficiently than any replacement, they recognized the value of retaining the pulpally/periapically involved teeth. Although many factors are responsible, the most important reason behind this growth is the extremely high predictability of success.

The objective of endodontic therapy is restoration of the treated tooth to its proper form and function in the masticatory apparatus, in a healthy state. Endodontic therapy consists of three basic phases namely: Diagnostic, Preparatory and Obturation phase. Every phase must be performed in a predetermined manner, with every step having its definite position in the series of procedures.

The primary goal of endodontics is not only to restore the tooth structure but also to increase the inherent strength of the remaining tooth structure.[18]

Fracture resistance is a mechanical property that describes the resistance of brittle materials to the catastrophic propagation of flaws under an applied load. It is proportional to the energy required to create new surfaces via crack propagation. Typical fracture resistance values of dental tissues are in the range of 0.7-1.3 $MNm^{-3/2}$ for enamel and 3.1 $MNm^{-3/2}$ for dentin.[64]

The system should provide enough strength and retention to support masticatory forces and should preserve tooth structure. The masticatory load on premolar region is 445 N.[3]

Sedgley and Messer[70] had reported that vertical root fracture is one of the failures that can occur during or after root canal treatment. The cumulative loss of tooth structure from caries, trauma, restorative and endodontic procedures increases susceptibility to fracture rather than from change in the properties of dentine after root canal treatment.[70]

Many other studies[17,50] have also suggested that as removal of tooth structure increases, fracture resistance of the tooth decreases. Endodontic procedures, biomechanical preparation & obturation have been blamed as a cause of vertical root fracture.

Furthermore pulpless teeth presents alteration of structural moisture content; the cumulative interaction of these factors can influence the mechanical properties of endodontically treated tooth. All these factors interact one after other with an increase in the occlusal load which cumulatively influence and increase the possibility of a root fracture.

The extracted teeth used in this study were fifty five; when extracted human teeth were used for the study, potential for large uncontrollable variations in strength exist. Therefore, all controllable factors should be standardized as much as possible. Each group of root specimens that were used consisted of randomly selected teeth of mandibular single-rooted premolars.[60,84]

According to a previous study, the mandibular first premolar had one canal at the apex in 74.0% of the teeth studied. So in the present study, mandibular first premolar teeth were selected.[93]

In this study, extracted single rooted human teeth were used to enhance the reliability of the investigation by duplicating the clinical situation. A straight rooted tooth with slight canal curvature was chosen because curved canal >20 degree would modify stress distribution.[75,90]

All the selected premolar teeth were having equal root lengths which were measured using digital vernier caliper.[82] The teeth were subjected to radiovisiography examination. Two radiographs were taken one in a bucco-lingual and other in a mesio-distal plane for studying the root canal anatomy and for eliminating teeth with irregularly shaped canals.[47]

The mechanical properties of dentin are largely determined by the intertubular dentin matrix, which is a complex composite of type I collagen fibers and a carbonate-rich apatite mineral phase. Maintaining the mechanical properties of tooth substrates is important during in vitro manipulations as well as being important for clinical tooth preparations. The mechanical property concerns regarding the handling of teeth for research purposes have prompted investigators[79,82] to evaluate the effects of storage in various storage media on hard tooth specimens as well as extracted teeth during transportation. An aqueous solution is essential for maintaining the hydration of the tooth samples prepared for mechanical testing. Hence in this study the teeth samples were stored in 0.9% normal saline solution for twenty four hours. The root canal preparations that resulted in a round cross-section imparts a more uniform stress distributions within a root during obturation, hence reducing fracture susceptibility.[92]

Canal preparation is one of the vital step of root canal treatment and is directly related to subsequent disinfection and filling. The aim of root canal preparation is to form a continuously tapered shape with the smallest diameter at the apical foramen and the largest at the orifice to allow effective irrigation and filling.[68] During the last decade, root canal preparation with rotary nickel-titanium (NiTi) instruments became popular as it facilitates the difficult and time- consuming process of shaping and improves the final quality of root canal preparation. In this study, Protraper Ni-Ti rotary system was used to produce round shaped canals. As single rooted extracted teeth were selected for the study, canal instrumentation was done till F3. Because of canal preparation and low curvature, orifice and canal are prepared large enough to allow a size of 15 K file to reach the apex.

During chemico-mechanical preparation, a layer of debris, the smear layer, is formed. Studies have shown that removal of the smear layer enhances the adhesion of sealers to the root canal wall.[37] The smear layer adheres to the canal walls and occludes the dentinal tubules (smear plugs). This negates the ability of medications to penetrate into deeper tissues, and prevents the filling material from optimally adhering to canal walls. Most authors[10,37] consider the removal of the smear layer important because it may be infected or it can prevent access to the dentinal tubules, which may contain bacteria and their by-products.

Several studies[7,28,100] have shown that the use of a combination of sodium hypochlorite (5.25%) and EDTA (17 %) is particularly effective in the removal of organic and inorganic debris. Hence during shaping and cleaning of the root canal systems, irrigants like 5.25% sodium hypochlorite and 17% Ethylenediaminetetraacetic acid (EDTA) solutions were used alternatively in this study and final irrigation was done with saline.

The current methods most frequently used in the canal obturation employ a semi-solid, solid or rigid cone cemented in the canal with the root canal cement used as a binding agent. The sealer is needed to:[37]

1. Fill in minor gaps and irregularities between the filling and the canal walls.

2. It acts as a lubricant and aids in seating of the cones.

3. It fills in the patent accessory canals and multiple foramina.

4. To reinforce the root canal dentin.

Johnson et al (2000)[36] recommended the use of adhesive sealers in the root canal system to reinforce the root filled teeth. Good adhesion to root canal dentin within the root canal is one of the ideal properties of sealer cements which potentially influence both microleakage and root strength.

Root canal sealers being used worldwide are based more on resin chemistry than on essential oil catalysts. It seems reasonable to assume that plastics, resins and glues should be more adhesive to dentin and less resorbable than the mineral oxide cements. So in one previous study[8] AH-26 and AH-Plus was found better as compared to zinc oxide cement sealer and also showed better dentinal tubule penetration and better root canal dentin reinforcement.

A new formulation of AH-26 is AH Plus Jet. It has the same formulation as AH Plus. It has an innovative double-barrel delivery syringe, so no need for manual mixing before use, enables direct and precise placement into the canal or onto a traditional mixing pad. Thus assures a better mixture in the necessary 1:1 ratio and does not release formaldehyde upon setting. It is an epoxy bisphenol resin, more radiopaque and has a shorter setting time (approximately 8 hours), lower solubility and better flow compared with AH-26 and also shows better fracture resistance as compared to other sealer. It exhibits a working time of approximately 4 hours. It can be placed in the root canal without any dentin preparation or dentin adhesive and can be used with any obturating technique.[69]

A sealer with epoxy resin penetrates better into the micro-irregularities, and as there is more cohesion between molecules, a greater mechanical interlock and better resistance to separation or removal occurs, thus producing increased adhesion.[78]

Over last few years, these MTA (i.e. calcium silicate) based materials have changed the MTA original formulation to improve the characteristics such as flow, setting time, and adhesion, allowing their use as endodontic sealer.[6] It is introduced in new paste–paste calcium silicate (MTA) based root canal sealer such a MTA Fillapex consist of mineral trioxide aggregate, salicylate resin, diluted resin, bismuth trioxide and nanoparticulated silica.[73] This root canal sealer has high radiopacity, low solubility in contact with tissue fluid, low expansion during setting and excellent viscosity for insertion.[61] This MTA based sealer shows better sealing ability as compared to calcium hydroxide or zinc oxide based root canal sealer, and has an antibacterial effect against E. faecalis before setting. It also has a high sealing capacity and it is the only root canal sealer that promotes cementum regeneration according to the manufacturers.[76] It is also biocompatible and stimulates mineralization.

Recently, a new bioceramic root canal sealer is introduced, which is commercially known as Endosequence BC sealer (Brasseler USA, Savannah, GA). It is a premixed and injectable endodontic sealer, because of its nanoparticle size it flow readily into canal irregularities and dentinal tubules. It is insoluble, hydrophilic, radiopaque and aluminiumfree material based on a calcium silicate composition. Being a hydrophilic, it utilises the moisture present in the dentinal tubules to initiate and complete its setting reaction. Due to shrinkage free setting, it results in a gap-free interface between gutta-percha, sealer and dentin.[31] Manufacture claims the sealer to be highly biocompatible and is antibacterial because of its highly alkaline pH during setting reaction.[102] Hence AH-Plus Jet, MTA Fillapex, Endosequence BC sealers were used in this study.

All the teeth in experimental groups were obturated with the gutta percha core material and the respective sealer using the matched taper single cone technique. Advantages of this technique include its predictability, relative ease of use, conservative preparation and controlled placement of materials. Radiographs of the root were then taken in bucco-lingual direction to confirm the adequacy of the root canal filling in terms of appropriate length, density and taper.

I – FRACTURE RESISTANCE.

The crosshead speed of the Instron universal testing machine is a user defined input with a maximum value of 700mm/min. Many different speeds to evaluate fracture resistance have been reported in the literature: 0.5mm/min,[13] 1mm/min,[4,38,82] 2mm/min,[44] 5mm/min,[97] 50mm/min,[40] and 500mm/min.[77]

Carvalho et al (2005)[12] suggested that a speed of 1mm/min simulated a compression force, while a higher speed on the order of 300mm/min could simulate an impact. In all of these studies the speed of the head on the Instron machine was reported, but no rationale was given for choosing the reported speed. The crosshead speed of 1 mm/min was chosen because it approximated to measure fracture resistance of root rather than measuring impact strength.[82,83]

Many different loading angles have been utilized in the literature to evaluate fracture resistance of different intracanal restorative materials. Several studies use a vertical load as a means to split the tooth,[13,38,61] 45º to the long axis of the tooth,[59,77] 90º to the facial surface of the tooth, 90º to the lingual surface of the tooth[29] and 130º to the lingual surface of the tooth.[44] Vertical load was chosen in this study because it simulates the average angle of contact between maxillary and mandibular premolars in class I occlusion[22] and transmits the force uniformly.

The results showed that **Group III** (Bioceramic based sealer) with a mean of 472.63 N had maximum fracture resistance followed by **Group I** (Negative control) having a mean of 472.14 N, **Group V** (Epoxy resin based sealer) having a mean of 462.09 N, **Group IV** (Calcium silicate based sealer) having a mean of 413.24 N, **Group V** (Positive control) having a mean of 335.91 N. Two test **Groups III and V** showed fracture resistance values as comparable to **Group I** (Negative control) indicating that root obturated with these root canal sealer was effective in reinforcing root strength as compared to group of no treatment.

In our study according to results obtained bioceramic based sealer i.e. Endosequence BC had shown high fracture resistance as compared to other root canal sealer used. The findings of this study are in agreement with **(Topcuoglu et al; 2013)**[87] who evaluated fracture resistance of bioceramic, epoxy resin and MTA based sealers and stated that bioceramic and epoxy resin based sealers increase the fracture resistance of root-filled single rooted premolar teeth.

The specimens in the **Group II** (Positive control) showed least fracture resistance than roots with bioceramic, epoxy resin and calcium silicate based sealer. This suggest that root canal sealers are necessary to seal the space between the dentinal wall and the obturating core interface, to fill voids and irregularities in the root canal, to fill lateral and accessory canals, and spaces between gutta-percha points used in lateral condensation. This confirmed that gutta percha should be used along with a sealer. These results are in agreement with results obtained by study performed by **(Shetty R et al; 2009)**[71]

The **Group V** (Epoxy resin based sealer) showed better fracture resistance than **Group IV and II.** The advantage of resin sealer can be because of greater adhesion of this sealer to root dentin as well as less volumetric shrinkage and high dimensional stability. These results were in accordance with study of **(Conbankara FK et al; 2002)**[17] and **(Sagsen B et al; 2012)**[61] who found that an epoxy resin based sealer demonstrated a better fracture resistance to calcium silicate based sealer.

Similar finding also supported by study performed by **(Shetty R et al; 2009)**[71] who reported that use of EDTA along with NaOCl removes the organic and inorganic content results in open dentinal tubules. The resin forms tags into these open dentinal tubules. Thus resin based sealers have been proposed to adhere to the root canal dentin and therefore reinforce endodontically treated teeth.

The **Group IV** (MTA based sealer) showed lowest mean fracture resistance values amongst experimental groups. This is in accordance with the findings of study of **Topcuoglu HS et al (2013)**[87] and **Sagsen et al (2012).**[61]

Reyes-Carmona et al (2009)[58] reported that the apatite formed by MTA and phosphate buffered saline was deposited within collagen fibrils, promoting controlled mineral nucleation on dentine, seen as the formation of an interfacial layer with tag-like structures. The reason for lower fracture resistance of calcium silicate based root canal sealer could be the low adhesion capacity of these tags like structure at interface of sealer with root dentin.

II – PUSH-OUT BOND STRENGTH.

Without use of an endodontic sealer an adequate seal cannot be obtained because gutta-percha does not bond spontaneously to the dentin walls.[45] Therefore, for good sealing ability an ideal endodontic cement should be present that should have both adhesive and cohesive strength to hold the obturation together and to root dentin.[24] In addition, the sealer should exhibit adequate flow for filling gaps between canal walls and gutta-percha cones which in turn contribute to the quality of sealing.

In static circumstances, spaces that might otherwise allow fluids to infiltrate into dentin-sealer interface are eliminated by the adhesion provided by sealer. Therefore endodontic filling materials may enhance the ability of root filled teeth to resist fracture.[61]

In dynamic situations, the adhesion is necessary for avoidance of dislodgement of the filling material during operative procedures. Hence reducing the risk of re-infection and contamination of the tooth.[61]

During mechanical preparation of the post space, filling material might get dislodged that may affect the quality of the seal by creating voids in the obturation.[16,19,20,65] Interfacial shear strength developed between different surfaces is an important factor to be considered during dislodgment of filling. Thus push-out test is widely used test to determine interfacial shear strength.[6]

In recent years, obturating materials and sealers have been developed based on dentin adhesion technologies borrowed from restorative dentistry, in an attempt to seal the root canal system more effectively. Thus, in the present study, push-out bond strength evaluation were carried out to determine interfacial shear strength of epoxy resin based, calcium silicate based, bioceramic based sealer.

Thin root slice, 1mm ± 0.1mm in thickness was obtained and subjected to push-out test. Values obtained in newtons (N) were converted into megapascals (MPa) by dividing the load in newtons (N) by the interface bonded area as carried out in study done by **Nagas et al;2012**.[53]

Results showed that, push-out bond strength of **Group III** (Epoxy resin based sealer) and **Group I** (Bioceramic based sealer) were significantly superior to that of **Group II** (MTA based sealer), but no significant difference between **Groups I** and **II** was found.

There is highly significant difference between bond strength of gutta-percha/epoxy resin based and gutta-percha/ MTA based sealers. Several studies, **Jainen et al 2007,**[33] **Alfredo et al 2008,**[1] **Ureyen Kaya et al 2008;**[91] have reported significantly higher bond strengths with epoxy resin based sealers.

Fisher et al 2007,[26] theorized the explanation for the superior adhesiveness to root dentin shown by epoxy resin based sealer as creation of a covalent bond by an epoxide ring to amino groups in collagen network. However the bonding capacity is not able to totally reduce the susceptibility of the roots to fracture.

In addition, epoxy resin based sealer also exhibits low solubility, good dimensional stability, low expansion, adhesion to dentin, good flow and hence coats the canal walls meticulously.

Epoxy resin sealer also shows better penetration into micro irregularities because of its creep capacity and long polymerization time, which increases the mechanical interlocking between the sealer and root dentin. Those properties facilitate the interlocking between sealer and dentin, which allied to the cohesion among molecules, promotes larger adhesion and higher resistance to dislodgement from dentin surface.[62,87]

But there was no significant difference between bond strength of Epoxy resin and Bioceramic based sealers. This finding is in agreement with the study of **Ersahan & Aydin (2010).**[24]

Zhang et al (2009),[102] who also reported similar apical sealing ability between iRoot SP (Bioceramic based sealer) and epoxy resin based sealer.

There is, significant difference between bond strength of bioceramic and MTA based sealers. This is in accordance with study done by **Sagsen et al (2011)**[62] in which MTA Fillapex was found to have least bond strength among the experimental groups.

Bouillaguet et al (2003)[9] stated that polymerization shrinkage stress that develop along the root dentin-sealer interface might result in debonding of the sealer.

According to **Zhang et al (2009)**; [102] high bond strength of Bioceramic based sealer may be explained by its calcium silicate composition, which uses the moisture naturally present in dentinal tubules to initiate and complete the setting reaction so that shrinkage free setting occurs.

In recent study by **Sonmez et al (2013)**[76] showed that MTA Fillapex has lowest bond strength to the dentin which may be due to voids in the sealer which can be reason for reduced fracture resistance as sealer is unable to adhere to root dentin.

The chemical composition of the MTA-based sealer could also influence its bonding behaviour. In a recent study, **Amin SW et al (2012)**[2] the reason for the low bond strength of MTA Fillapex was claimed to be the low adhesion capacity of tag-like structures because of apatite formation by MTA.

The findings of mode of failure by stereomicroscope examination at 30X correlate well with the results of the push-out test in which increased resistance to dislocation decreases the likelihood of dislodgement of sealer-dentin interface and increases the likelihood that failure will occur within sealer itself. This would explain why epoxy resin and bioceramic based sealers showed higher push-out strength than MTA based sealer, also had higher prevalence of cohesive failure (70% for bioceramic and 80% for epoxy resin) than MTA Fillapex (60%). While only MTA Fillapex exhibit adhesive mode of failure (20%).

Thus, considering the results and within the limitation of present study, it can be concluded that bioceramic based sealer exhibit increased fracture resistance among the other sealers and epoxy resin based sealer exhibit increased bond strength to dentin among the other sealers.

This experimental study was limited to only vertical root fracture, a catastrophic fracture does not occur normally under normal function. The load to failure may not directly relate to fracture resistance of bonded root filling materials and root structure. Cyclic loading by applying force in different directions may simulate the chewing forces in the clinical situation and may be used to investigate other types of tooth fracture under function.

The weakening effect of sodium hypochlorite and EDTA on dentin was not considered in this study; as previous study had shown reduced modulus of elasticity, flexural strength and microhardness of dentine after exposure to 5.25% sodium hypochlorite and EDTA. This may be caused by a decrease in stiffness of intertubular dentin matrix caused by heterogeneous distribution of the mineral phase within the collagen matrix and might be due to depletion of the organic phase after NaOCl treatment may cause mechanical change.

Although these are in vitro results, they are of significance because these factors cannot easily be quantitatively determined in vivo.

Summary

SUMMARY.

The present study was undertaken for comparative evaluation of the fracture resistance of obturated roots and push-out bond strengths to root dentin with three different sealers namely epoxy resin, MTA and bioceramic based root canal sealers with the help of universal testing machine (Instron).

Fifty-five extracted caries free and visually assessed fracture free, human single rooted mandibular premolar teeth were selected for the study. Each tooth was sectioned with a diamond disc under constant irrigation, 1mm coronal to the cemento-enamel junction measuring root specimens of 14 mm in length. Out of fifty-five teeth, forty teeth were subjected to fracture resistance evaluation; whereas remaining fifteen teeth for push-out bond strength evaluation.

The canals were prepared with endodontic rotary handpiece and NiTi rotary file system and 5.25% sodium hypochlorite and 17% Ethylenediaminetetraacetic acid (EDTA) solutions were used to irrigate the canal throughout instrumentation and then rinsed with saline and dried with paper points.

For fracture resistance: The prepared teeth were randomly divided into three experimental groups of 10 teeth each and two control groups of 5 teeth each.

Group- I: Unprepared and unfilled (negative control group).

Group- II: Prepared and filled (positive control group).

Group- III: Canals obturated with gutta percha and Bioceramic based sealer.

Group IV: Canals obturated with gutta percha and Calcium silicate based sealer.

Group V: Canals obturated with gutta percha and epoxy resin based sealer.

The entire root samples were mounted in an acrylic resin base with the help of a copper rings. Then the samples were tested on the Universal testing machine for fracture resistance and the results were obtained in Newton's (N).

All the results were statistically analyzed using One way ANOVA and Post-hoc tukey test.

Based on the results obtained and the statistical analysis the following conclusions were drawn.

The root sample obturated with the gutta-percha and Bioceramic based sealer was effective in increasing the fracture resistance and compared to the control groups. The maximum mean fracture resistance was for **Group III (Bioceramic based root canal sealer)** and minimum for **Group II (prepared and unfilled)**. Hence the values suggest that roots obturated with **Group III (Bioceramic based root canal sealer)** is most effective in increasing the fracture resistance followed by **Group V (Epoxy resin based sealer), Group IV (Calcium silicate based sealer) and Group II (prepared and unfilled)** which is least effective. Values are similar for both **Group I (unprepared and unfilled)** and **Group III (Bioceramic based sealer).**

For Push-out bond strength: Fifteen root specimens were divided into three groups. Each root specimen were cut into two 1mm thick transverse section each by using a water cooled precision saw to obtain 10 thin slice section of 1mm per group; which are

Group-I: Thin slice of specimens obturated with GP + Bioceramic based sealer.

Group-II: Thin slice of specimens obturated with GP+ MTA based sealer.

Group-III: Thin slice of specimens obturated with GP + Epoxy resin based sealer.

Then the slice were tested on the Universal testing machine for push-out bond strength and the results were obtained in Megapascal (MPa). After debonding, each root slice were examined under stereomicroscope at 30X magnification for assessment of mode of failure.

All the results were statistically analyzed using One way ANOVA and Post-hoc tukey test. Based on the results obtained and the statistical analysis the following conclusions were drawn.

Epoxy resin based sealer (Group III) exhibits the higher bond strength to root dentin followed by **Group I (Bioceramic sealer)** and **Group II (MTA based sealer)** which exhibit the least. Cohesive mode of failure of debonding were largely exhibited by **Group III and I** with adhesive mode shown only by **Group II.**

Conclusion

CONCLUSION.

Based on the results obtained and discussed, the following conclusions were drawn from the present study:-

- All three sealers, in turn increases the fracture resistance of obturated root.
- Among the root canal sealers; **Bioceramic based sealer (i.e. Endosequence BC)** showed higher resistance to fracture than epoxy resin and MTA based sealers and almost similar to roots with no instrumentation and obturation.
- **Epoxy resin based sealer (i.e. AH-Plus Jet)** had greater resistance to push-out bond strength than **MTA based sealer (i.e. MTA Fillapex)** with gutta-percha, but comparable resistance to that of **Bioceramic based sealer (i.e. Endosequence BC).**
- **MTA Fillapex** showed the least resistance to push-out among the other tested sealers which might provide a certain advantage to the **AH-Plus Jet** and **Endosequence BC** sealers when a post preparation is required.

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